NOAA FISHERIES
Alaska Fisheries Science Center

Assessment of Pacific cod in the eastern Bering Sea

Grant Thompson

November 18, 2014

Team and SSC comments

Comments on assessments in general (1 of 3)

- JPT1 (9/13 minutes): *"The Teams recommended that SAFE chapter authors continue to include 'other' removals as an appendix. Optionally, authors could also calculate the impact of these removals on reference points and specifications, but are not required to include such calculations in final recommendations for OFL and ABC."* "Other" removals are presented in Appendix 2.2
- JPT2 (9/13 minutes): *"In conformity with the main recommendations of the working group, the Teams recommended the following:*
  1. *Assessment authors should routinely do retrospective analyses extending back 10 years, plot spawning biomass estimates and error bars, plot relative differences, and report Mohn's rho (revised).*
  2. *If a model exhibits a retrospective pattern, try to investigate possible causes.*
  3. *Communicate the uncertainty implied by retrospective variability in biomass estimates.*
  4. *For the time being, do not disqualify a model on the grounds of poor retrospective performance alone.*
  5. *Do consider retrospective performance as one factor in model selection."*

  See "Results" section, under "Model Evaluation" and also a new subsection entitled "Retrospective Analysis," located under "Time Series Results"

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Comments on assessments in general (2 of 3)

- JPT3 (9/13 minutes): *"The Teams recommended that each stock assessment model incorporate the best possible estimate of the current year's removals. The Teams plan to inventory how their respective authors address and calculate total current year removals. Following analysis of this inventory, the Teams will provide advice to authors on the appropriate methodology for calculating current year removals to ensure consistency across assessments and FMPs."* This comment is addressed under the "Standard Harvest Scenarios, Projection Methodology, and Projection Results" subsection of the "Results" section
- SSC1 (10/13 minutes): *"We agree with the recommendations of the Plan Team that retrospective analyses extending back 10 years and including Mohn's revised ρ, should routinely be presented in the assessments, and that retrospective patterns should be taken into consideration when selecting a model and when communicating uncertainties associated with biomass estimates. The SSC also notes that a strong retrospective bias should be one of the criteria considered when setting ABCs and could provide justification for recommending a higher or lower ABC."* See response to comment JPT2; also, consideration of retrospective bias in the context of ABC is addressed in the "Harvest Recommendations" subsection of the "Results" section

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Comments on assessments in general (3 of 3)

- SSC2 (12/13): *"During public testimony, it was proposed that assessment authors should consider projecting the reference points for the future two years (e.g., 2014 and 2015) on the phase diagrams. It was suggested that this forecast would be useful to the public. The SSC agrees. The SSC appreciated this suggestion and asks the assessment authors to do so in the next assessment."* Figure 2.15 includes projected values for the next two years.
- JPT4 (9/14): Regarding catch projections, *"the Teams recommend that authors choose a method that appears to be appropriate for their stock, and this method be clearly documented. The Teams recommend authors establish their best available estimate of catch in the current year and the next two years. The Teams recommend that authors should also document how those projected catches were determined in the Harvest Recommendations section (ideally Scenario 2)."* See response to comment JPT3; also, estimation of projected catches is addressed in the same subsection, and those estimated catches are used in Scenario 2
- SSC3 (10/14): Regarding comment JPT4, *"The SSC supports these recommendations."* See response to comments JPT3 and JPT4

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Comments on this assessment

- 19 comments addressed in preliminary assessment; not repeated here
- BPT1 (9/14 minutes): *"The Team recommends that the author present fits of Models 1 and 6 in November. The L1 parameter of Model 6 should be estimated as a single rather than time-varying value to stiffen the fit and eliminate the questionable values in the series of annual estimates of L1."* Models 1 and 6 from the preliminary assessment are included here as Models 1 and 2; the *L1* parameter is now time-invariant in both models
- SSC4 (10/14 minutes): *"The SSC agrees with the Plan Team and also notes that the laborious re-weighting procedure does not need to be repeated for Model 6. The SSC also agrees with the Plan Team regarding estimation of a single L1 parameter for growth instead of the annual estimates."* See response to comment BPT1; also, the iterative tuning process that was used to estimate certain parameters in Model 6 (now Model 2) during the preliminary assessment was not repeated here.

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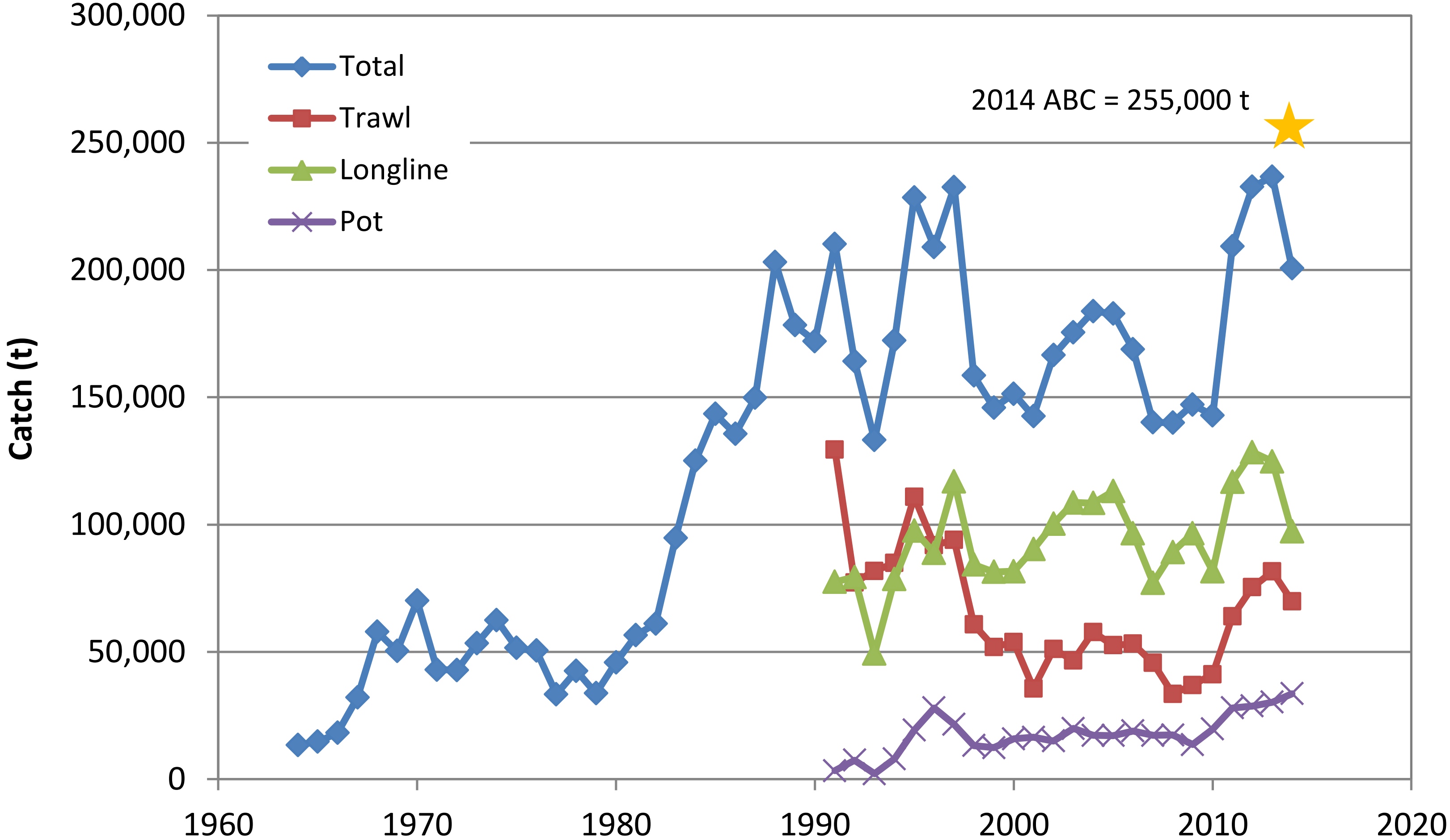
Data highlights

Catch history (2014 data are incomplete)



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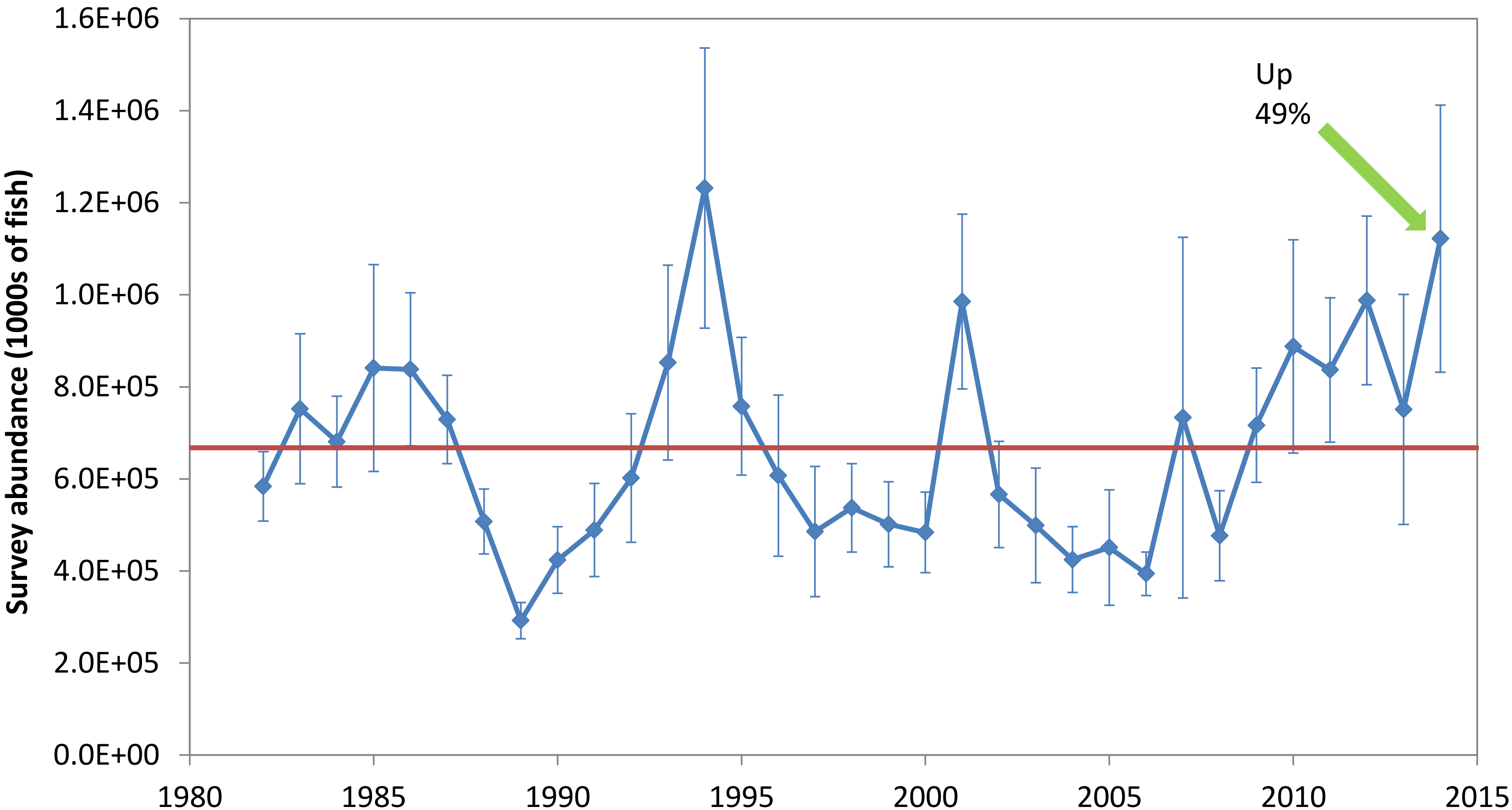
Survey numbers history



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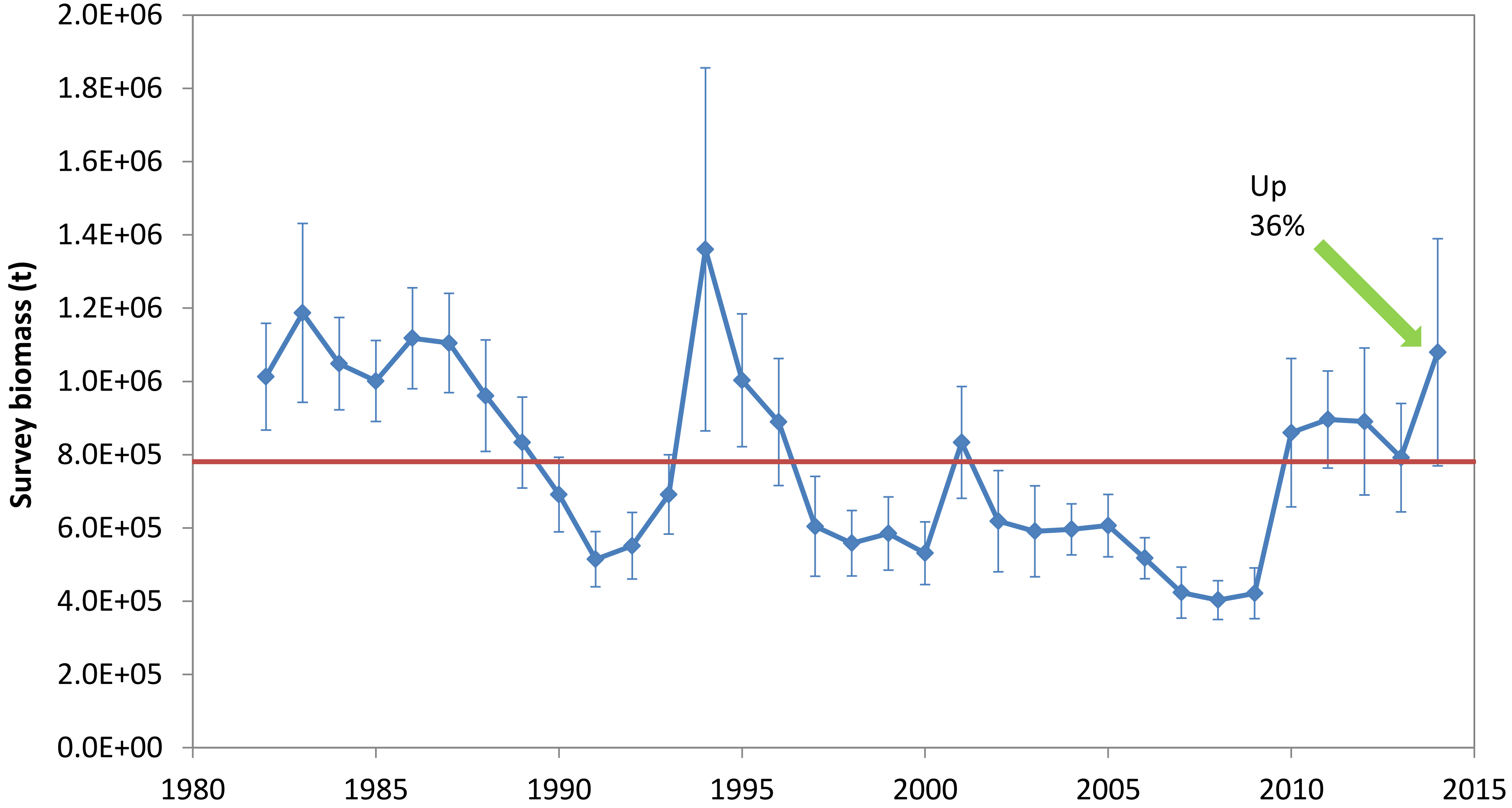
Survey biomass history (not used in models)



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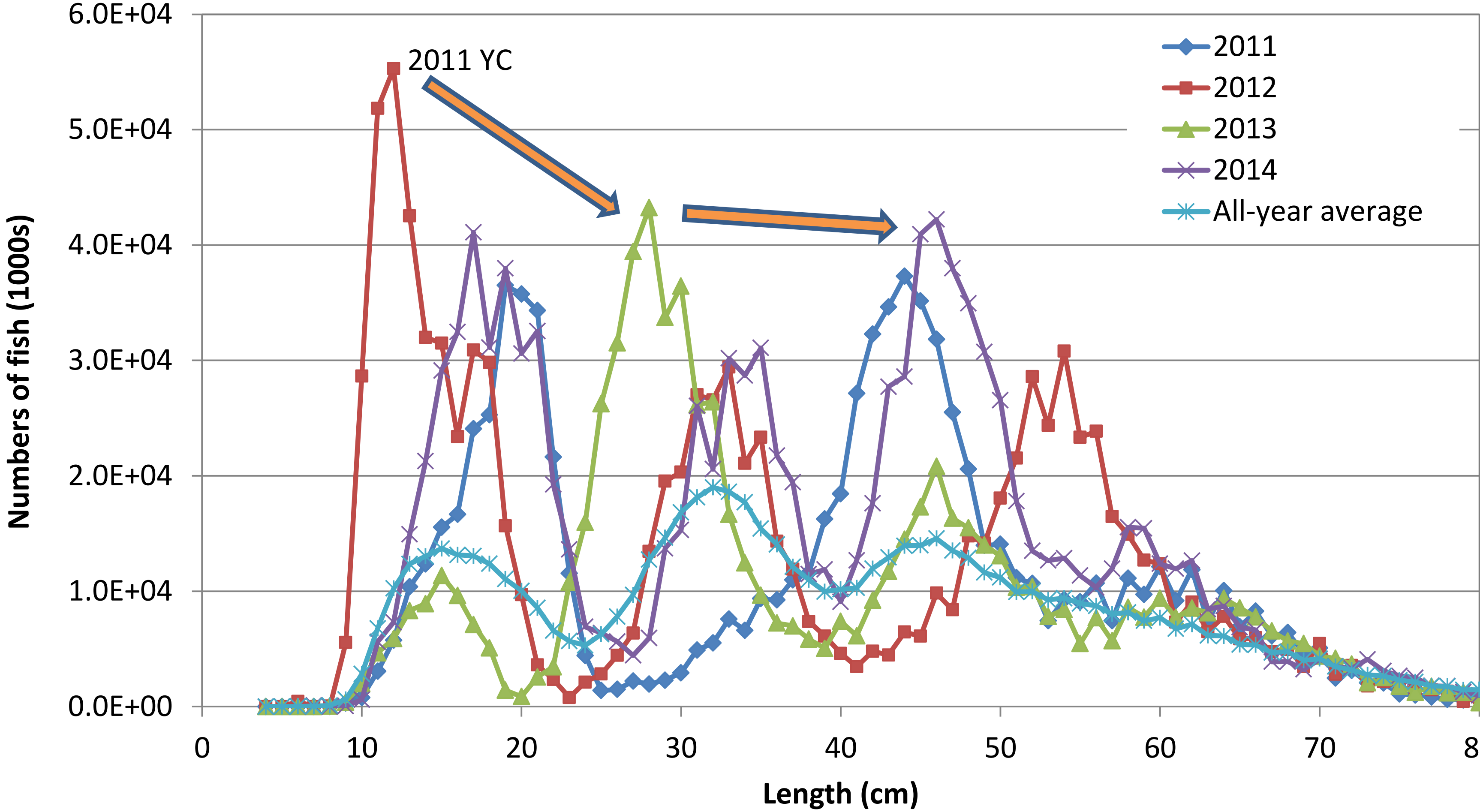
Recent survey length compositions



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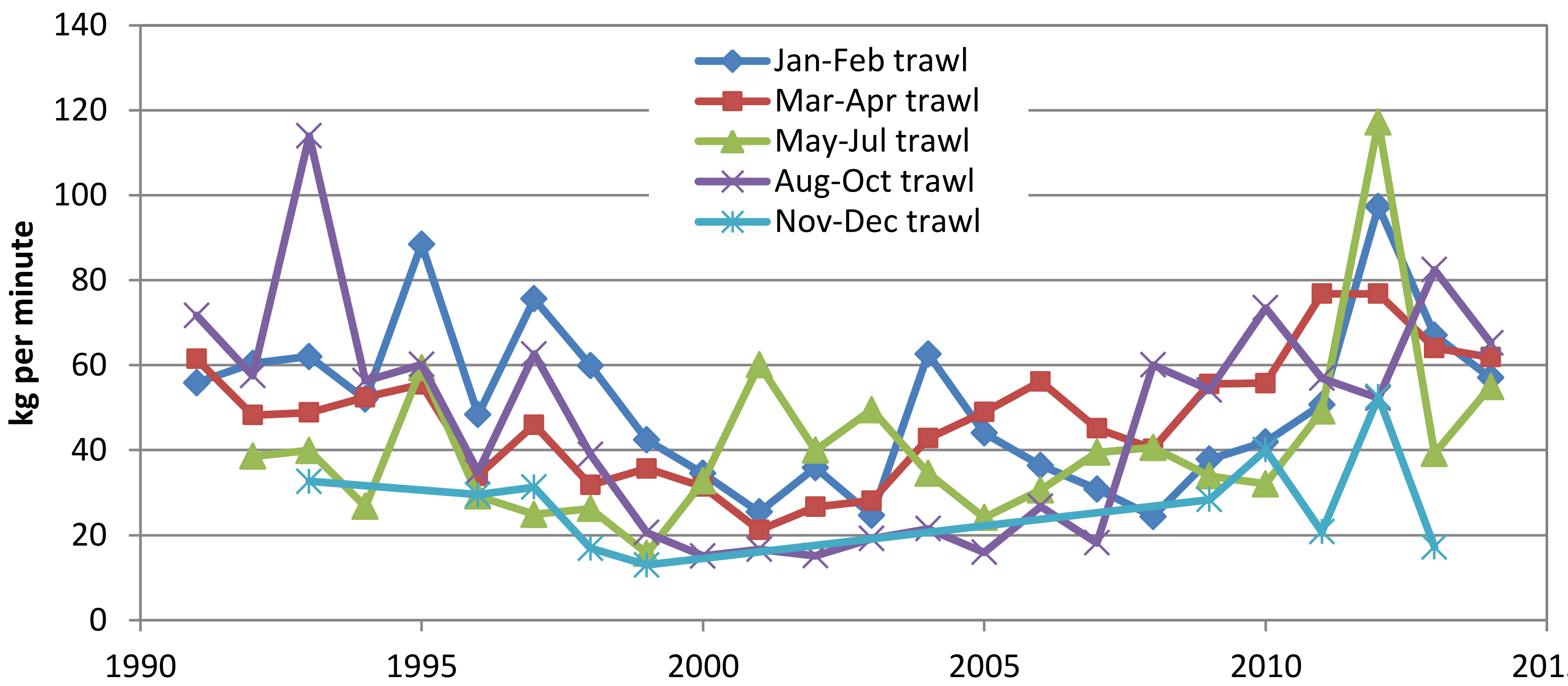
CPUE (not used in model): trawl fishery



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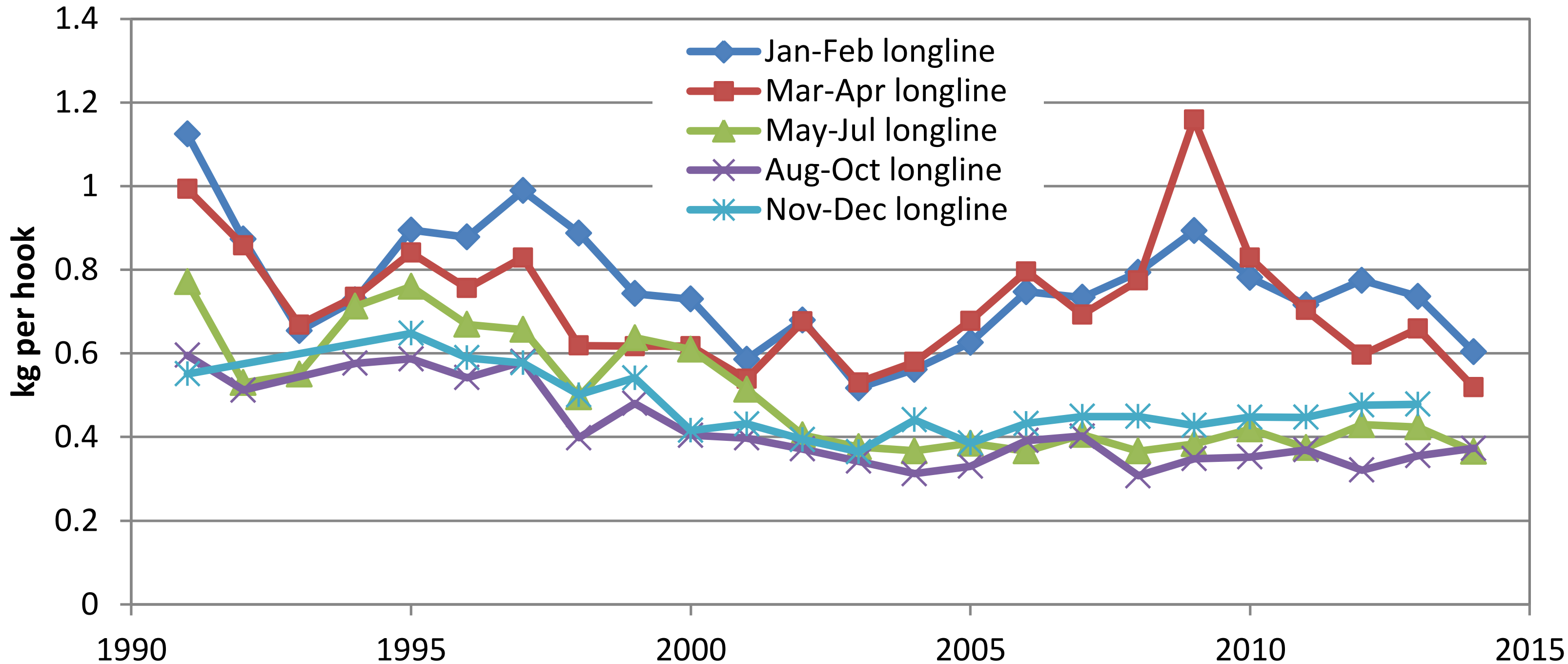
CPUE (not used in model): longline fishery



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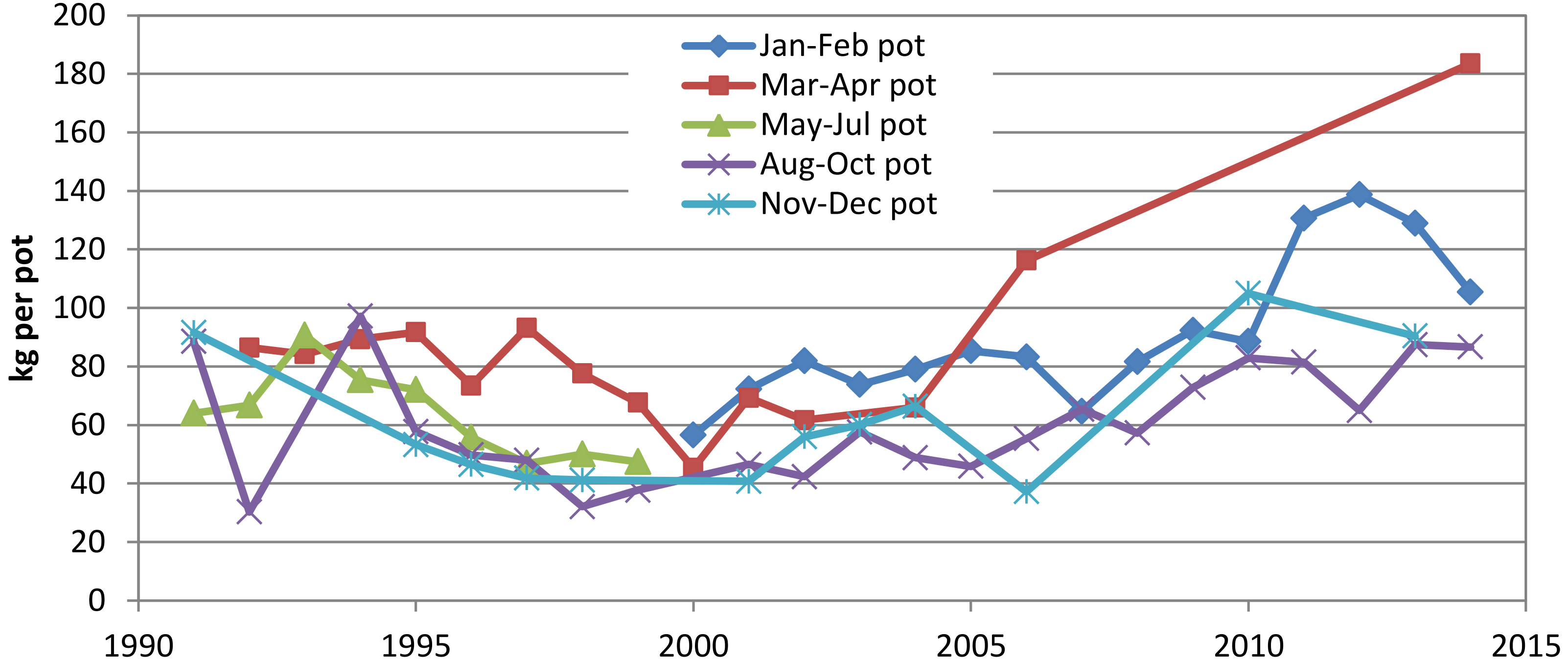
CPUE (not used in model): pot fishery



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Model structures

Model 1 structure (1 of 3)

- Age- and time-invariant natural mortality, estimated outside the model
- Parameters governing time-invariant mean length at age estimated internally
- Parameters governing width of length-at-age distribution (for a given mean) estimated internally
- Ageing bias parameters estimated internally
- Standard deviations of *dev* vectors fixed at the values estimated in 2009

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Model 1 structure (2 of 3)

- Survey catchability fixed at the value estimated in 2009 (based on Nichol et al. 2007)
- Gear-and-season-specific catch and selectivity for the fisheries
- Double normal selectivity for fisheries and survey
- Length-based selectivity for the fisheries
- Age-based selectivity for the survey
- Fishery selectivity estimated for “blocks” of years

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Model 1 structure (3 of 3)

- Survey selectivity constant over time, except with annual *devs* for the *ascending_width* parameter
- Survey size composition data used in all years, including those years with age composition data
- Fishery CPUE data included but not used for estimation
- Mean size at age included but not used for estimation

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Model 2 differences from Model 1 (1 of 2)

1. Each year consists of a single season
   - Model 1 uses 5 “catch seasons” and 3 “selectivity seasons”
2. A single fishery is defined
   - Model 1 uses 15 “catch fisheries” and 9 “selectivity fisheries”
3. The survey is assumed to sample age 1 fish at true age 1.5
   - Model 1 uses true age 1.41667
4. Initial abundances are estimated for the first 10 age groups
   - Model 1 estimates the first 3
5. The natural mortality rate is estimated internally
   - Model 1 sets M=0.34

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Model 2 differences from Model 1 (2 of 2)

6. The base value of Q is estimated internally
   - Model 1 sets Q=0.77
7. Survey catchability is allowed to vary annually
   - Model 1 uses a constant value
8. All selectivity parameters are (potentially) allowed to vary annually
   - Model 1 uses time blocks for some fishery selectivity parameters, annual $devs$ for 1 survey selectivity parameter
9. Selectivities are modeled using a random walk with respect to age (see next two slides)
   - Model 1 uses the double normal

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Approaches to selectivity parameterization

1. Selectivity is forced to follow some assumed form
   - Parsimonious, but what if the assumed form is wrong?
2. One selectivity parameter for each age, with parameters estimated independently of each other
   - Flexible, but not parsimonious
3. One selectivity parameter for each age, with between-age changes in parameters constrained by priors
   - May combine the best features of first two approaches
   - Note the distinction between forcing *selectivity itself* to follow an assumed form and forcing *the mean of the priors* to follow an assumed form

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SS selectivity-at-age pattern #17

- SS selectivity-at-age pattern #17 is based on backward 1st differences of log selectivity
  - These backward 1st differences (not selectivities at age *per se*) are the ADMB "init" parameters
- Priors must be specified for each age (may be uniform)
- Model 2 uses normal priors, with:
  - Age-specific means estimated iteratively so as to give the best fit of a logistic curve to the estimated selectivities
  - Constant (across age) standard deviation estimated iteratively so that the minimum (w.r.t. age) CV of the estimated selectivities is 50%

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Iterative tuning of Model 2 involved 3 loops

1. Iterative tuning of prior distributions for selectivity parameters
2. Iterative tuning of time-varying parameters other than Q, which involved the following steps:
   A. Iteratively estimating "unconstrained" values of the standard deviations of the *devs* for log recruitment and all selectivity parameters
   B. Iteratively estimating "iterated" values of the standard deviations of the *devs* for the above parameters
   C. Computing final values of the standard deviations of the *devs* of the above parameters by the method of Thompson and Lauth (2012)
3. Iterative tuning of time-varying Q:
   - The procedure for tuning time-varying Q was different because, unlike the sizecomp or agecomp data, the time series of survey abundance includes a statistically derived time series of standard errors
   - The procedure involved iteratively adjusting the standard deviation until the root-mean-squared-standardized-residual equaled unity

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Estimated parameters common to all models

- Von Bertalanffy growth parameters
- Standard deviation of length at ages 1 and 20
- Ageing bias at ages 1 and 20
- Log mean recruitment since the beginning of the time series
- Offset for log mean recruitment prior to beginning of series
- Vector of *dev*s for log-scale initial abundance at ages 1-3
- Annual log-scale recruitment *dev*s for 1977-2012
- Initial (equilibrium) fishing mortality
- Base values for all fishery and survey selectivity parameters
- Fishing mortality rates (but these are done differently in SS)

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Other internally estimated parameters

- Natural mortality rate (Model 2)
- Richards growth parameter (Model 2)
- Vector of *devs* for initial abundance at ages 3-10 (Model 2)
- Base value of Q (Model 2)
- Annual *devs* for Q (Model 2)
- Block-specific fishery selectivity parameters (Model 1)
- Annual *devs* for fishery age 4 selectivity parameter (Model 2)
- Annual *devs* for survey age 2 selectivity parameter (Model 2)

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Results

Objective function and parameter counts

- Objective function components:

Obj. func. component	Model 1	Model 2
Equilibrium catch	0.01	0.00
Survey abundance index	-3.61	-60.32
Size composition	4948.11	992.08
Age composition	141.27	104.30
Recruitment	21.62	-0.11
Priors	n/a	14.77
"Softbounds"	0.03	0.00
Deviations	19.85	13.05
"F ballpark"	0.00	0.17
Total	5127.28	1063.93

- Parameter counts:

Parameter counts	Model 1	Model 2
Unconstrained parameters	115	13
Parameters with priors	0	73
Constrained deviations	71	117
Total	186	203

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Fit to CPUE and survey abundance: statistics

- RMSE = root mean squared error (average survey log-scale standard error = 0.11)
- MNR = mean normalized residual
- SDNR = standard deviation of normalized residuals
- Corr. = correlation (observed:expected)

Model	Fleet	RMSE	MNR	SDNR	Corr.
1	Jan-Apr trawl fishery	0.45	0.55	3.76	0.17
1	May-Jul trawl fishery	0.38	-0.15	1.61	0.34
1	Aug-Dec trawl fishery	0.69	0.19	2.37	0.13
1	Jan-Apr longline fishery	0.35	0.23	4.24	-0.10
1	May-Jul longline fishery	0.26	0.31	2.40	0.50
1	Aug-Dec longline fishery	0.23	0.15	3.58	0.35
1	Jan-Apr pot fishery	0.34	0.17	1.93	0.22
1	May-Jul pot fishery	0.21	0.04	1.51	0.21
1	Aug-Dec pot fishery	0.38	0.01	2.03	0.13
1	Shelf trawl survey	0.23	0.99	1.86	0.76
2	Shelf trawl survey	0.11	0.10	0.94	0.93

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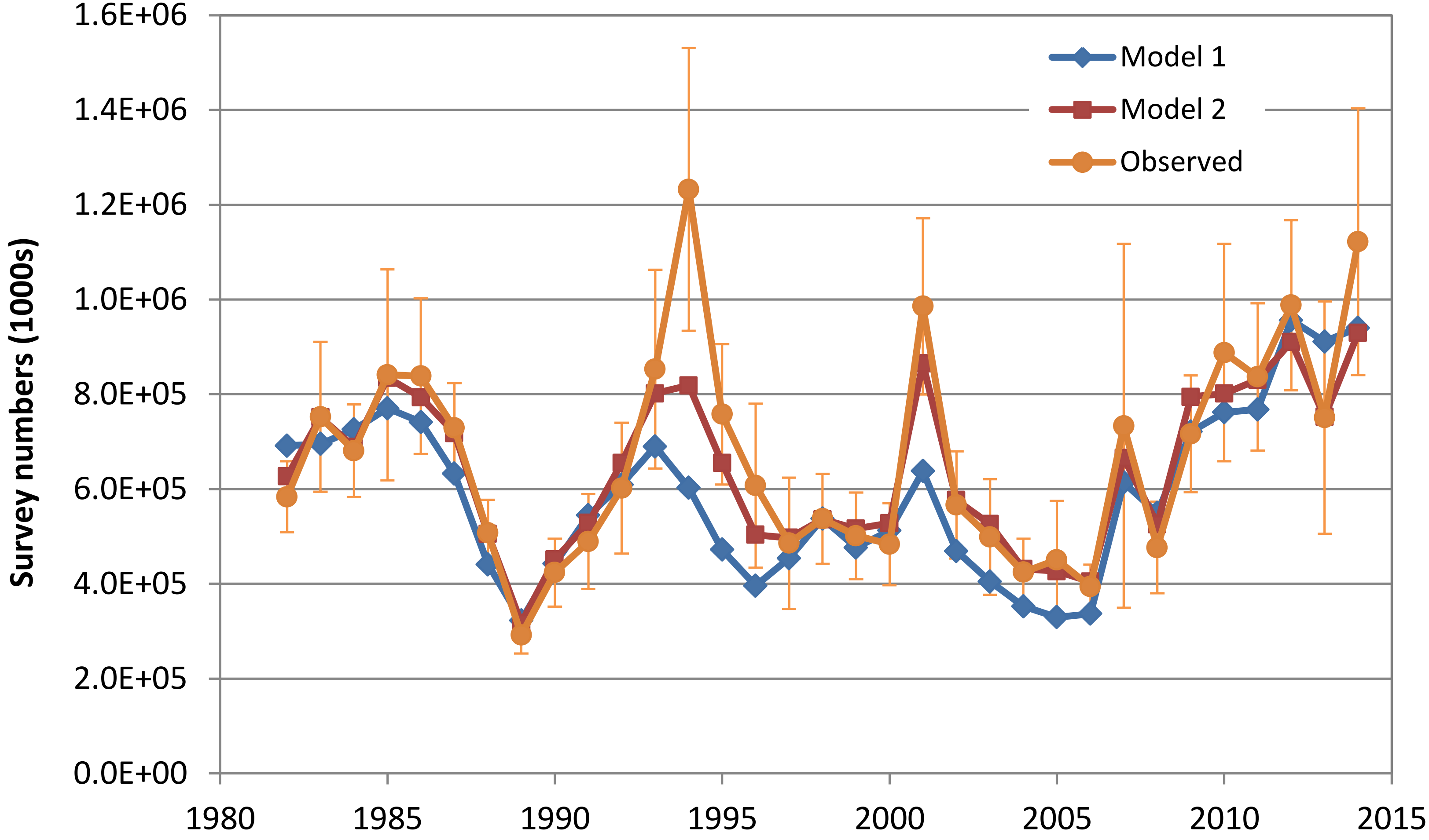
Fit to survey abundance: figure



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Fit to size composition data: statistics

- Nrec = number of records
- Ninp = input sample size
- Neff = effective sample size
- A(·) = arithmetic mean
- H(·) = harmonic mean

				Ratios		
Mod.	Fleet	Nrec	A(Ninp)	A(Neff/Ninp)	A(Neff)/A(Ninp)	H(Neff)/A(Ninp)
1	Jan-Apr trawl fish.	66	318	5.06	3.00	1.66
1	May-Jul trawl fish.	34	63	9.14	7.31	3.33
1	Aug-Dec trawl fish.	36	44	13.20	6.00	3.35
1	Jan-Apr longline fish.	70	471	8.54	4.00	1.16
1	May-Jul longline fish.	34	244	9.39	5.23	3.02
1	Aug-Dec longline fish.	65	669	6.43	3.15	0.88
1	Jan-Apr pot fish.	38	131	14.30	9.78	3.90
1	May-Jul pot fish.	16	136	18.56	7.79	1.84
1	Aug-Dec pot fish.	38	83	10.15	7.38	2.93
1	Trawl survey	33	282	2.01	1.71	1.05
2	Fishery	38	300	13.66	9.50	2.67
2	Trawl survey	33	300	2.33	1.98	1.23

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Fit to age composition data: statistics

Year	Input N	Effective N		Ratio	
		Model 1	Model 2	Model 1	Model 2
1994	204	400	240	1.96	1.18
1995	163	39	67	0.24	0.41
1996	203	303	588	1.50	2.90
1997	205	175	505	0.85	2.46
1998	181	1423	2046	7.86	11.30
1999	245	112	72	0.46	0.29
2000	245	90	58	0.37	0.24
2001	263	103	93	0.39	0.35
2002	248	82	85	0.33	0.34
2003	360	260	523	0.72	1.45
2004	284	30	59	0.11	0.21
2005	365	401	317	1.10	0.87
2006	371	143	405	0.39	1.09
2007	411	64	1494	0.16	3.64
2008	346	249	568	0.72	1.64
2009	403	100	440	0.25	1.09
2010	369	103	262	0.28	0.71
2011	358	193	136	0.54	0.38
2012	371	112	124	0.30	0.33
2013	405	129	229	0.32	0.56
Mean	300	226	416	0.94	1.57
Harm.	272	106	156	0.37	0.58

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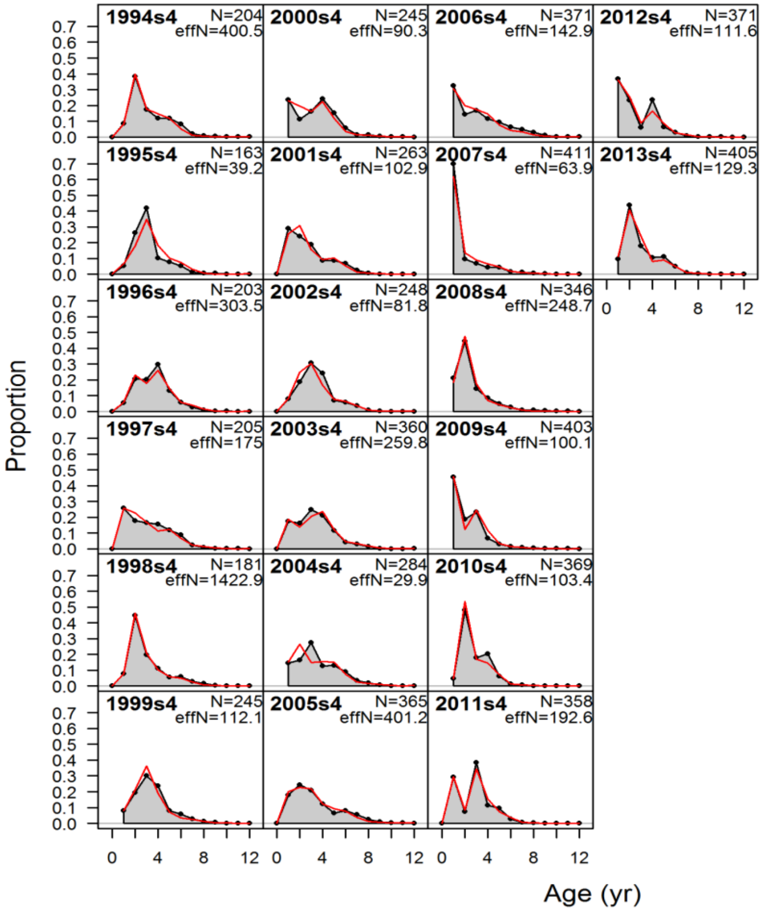
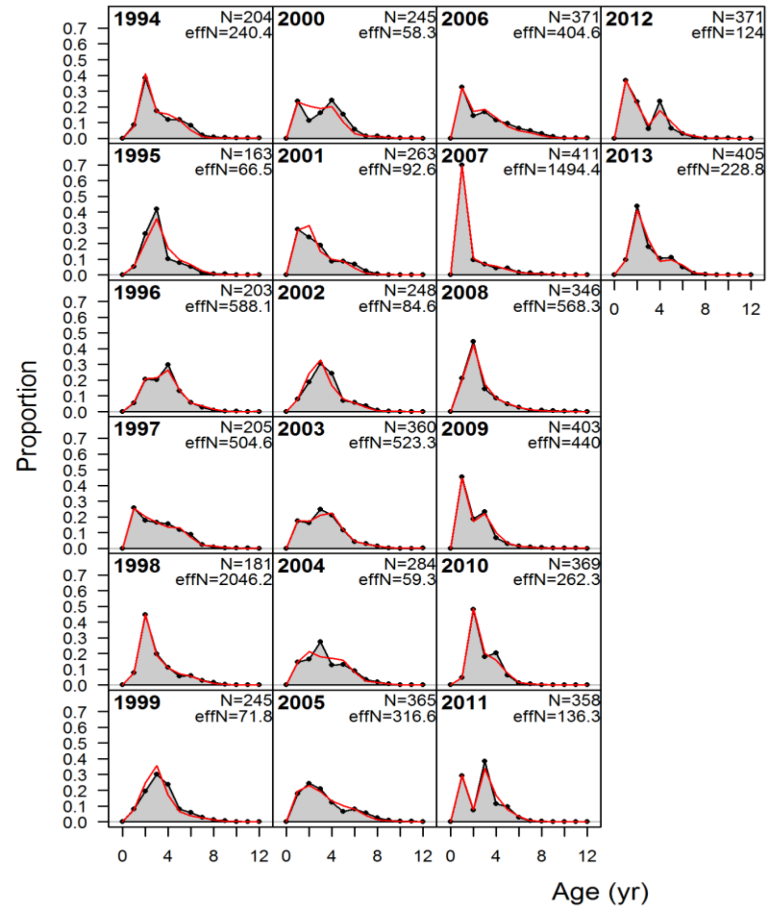
Fit to survey age compositions: pictures

- Model 1



Model 2



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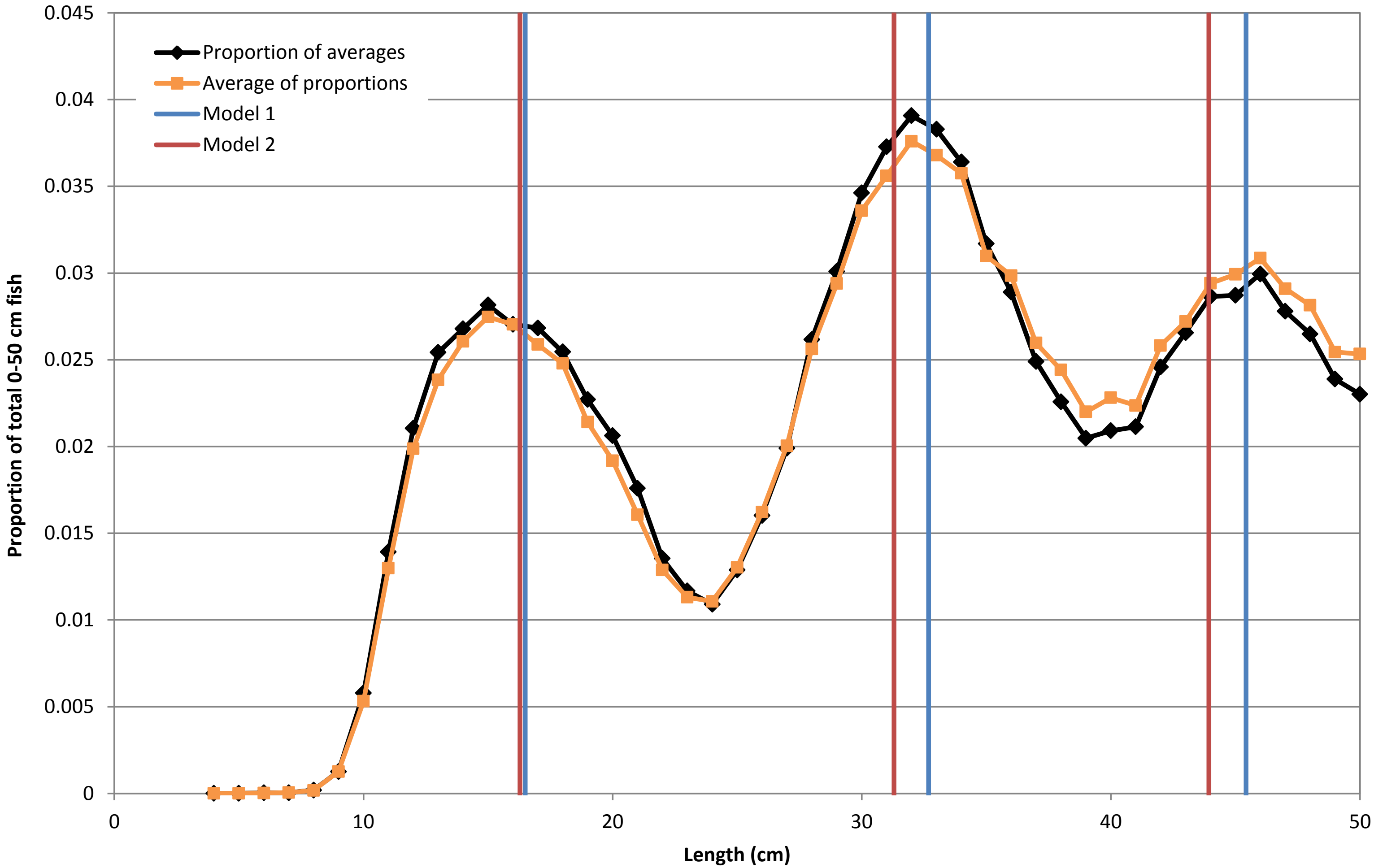
Mean size at age versus survey size modes



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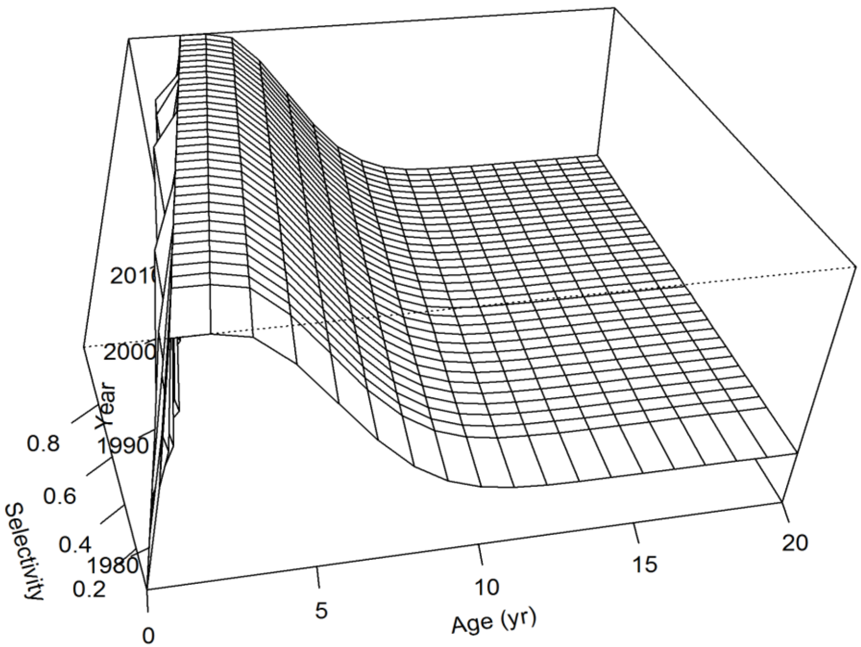
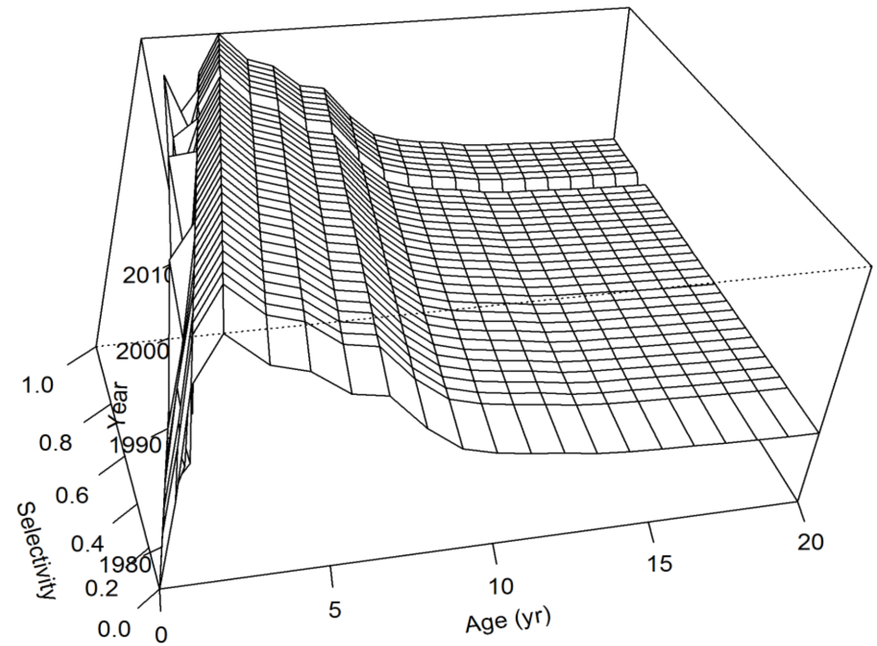
Survey selectivity

- Model 1



Model 2



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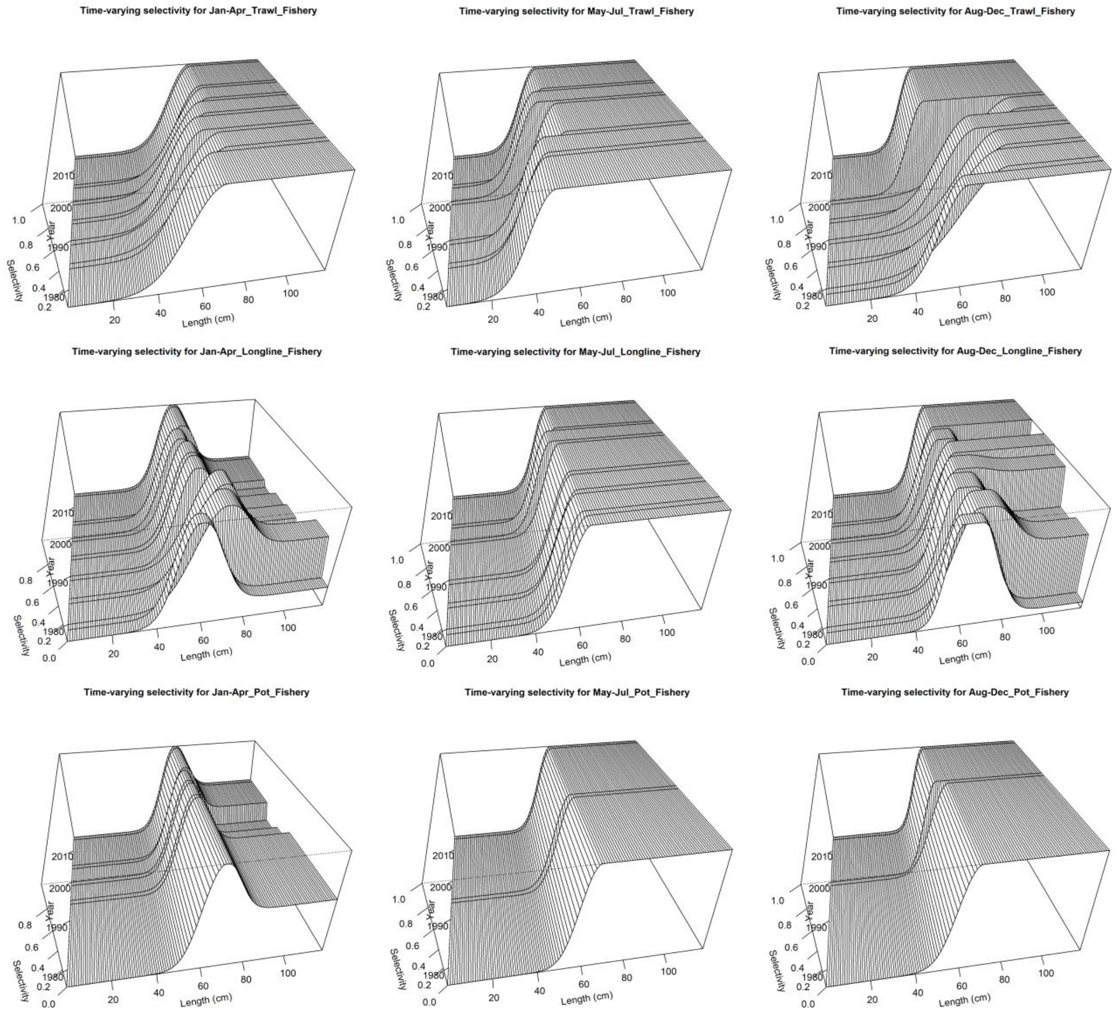
Fishery selectivity (Model 1, gear x season)



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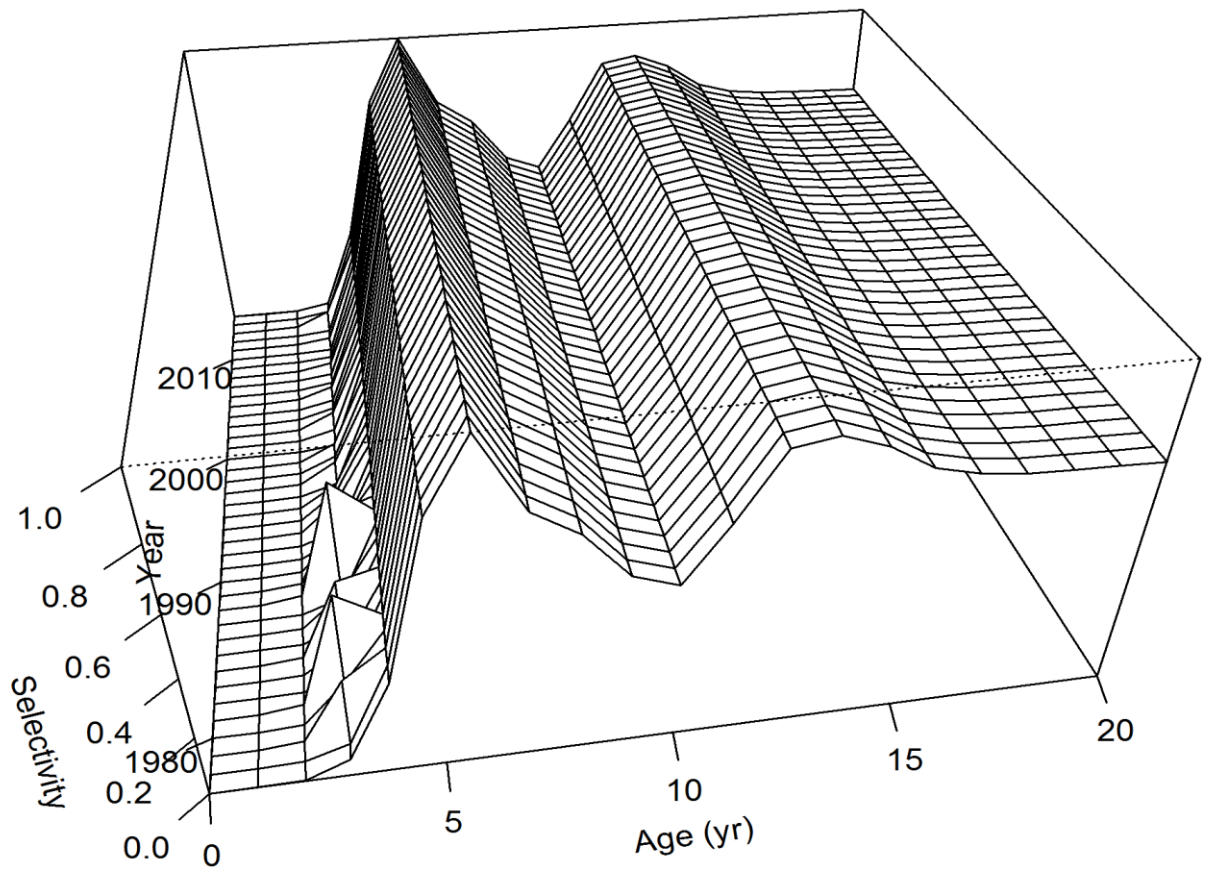
Fishery selectivity (Model 2)



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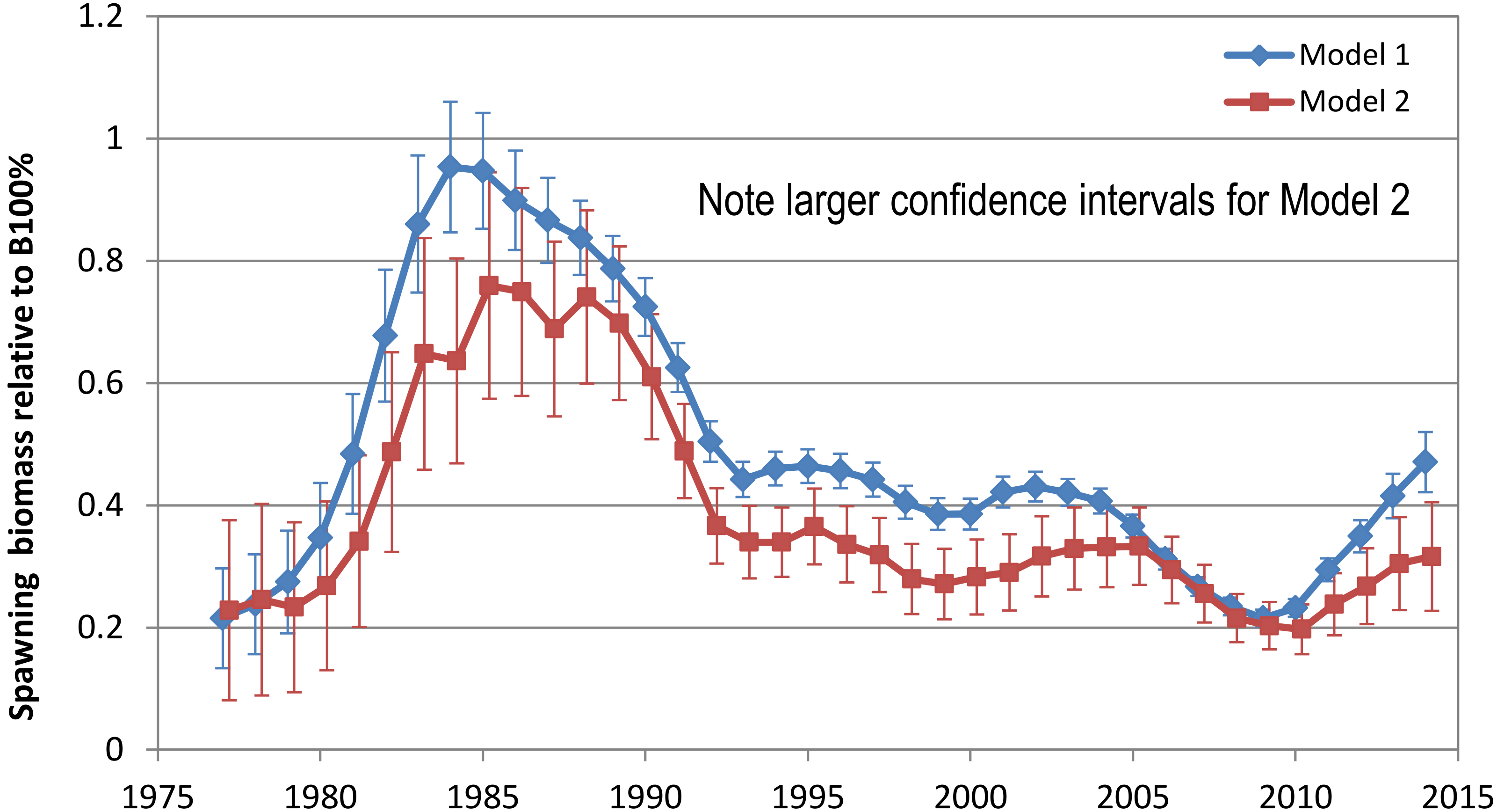
Spawning biomass relative to $B_{100\%}$



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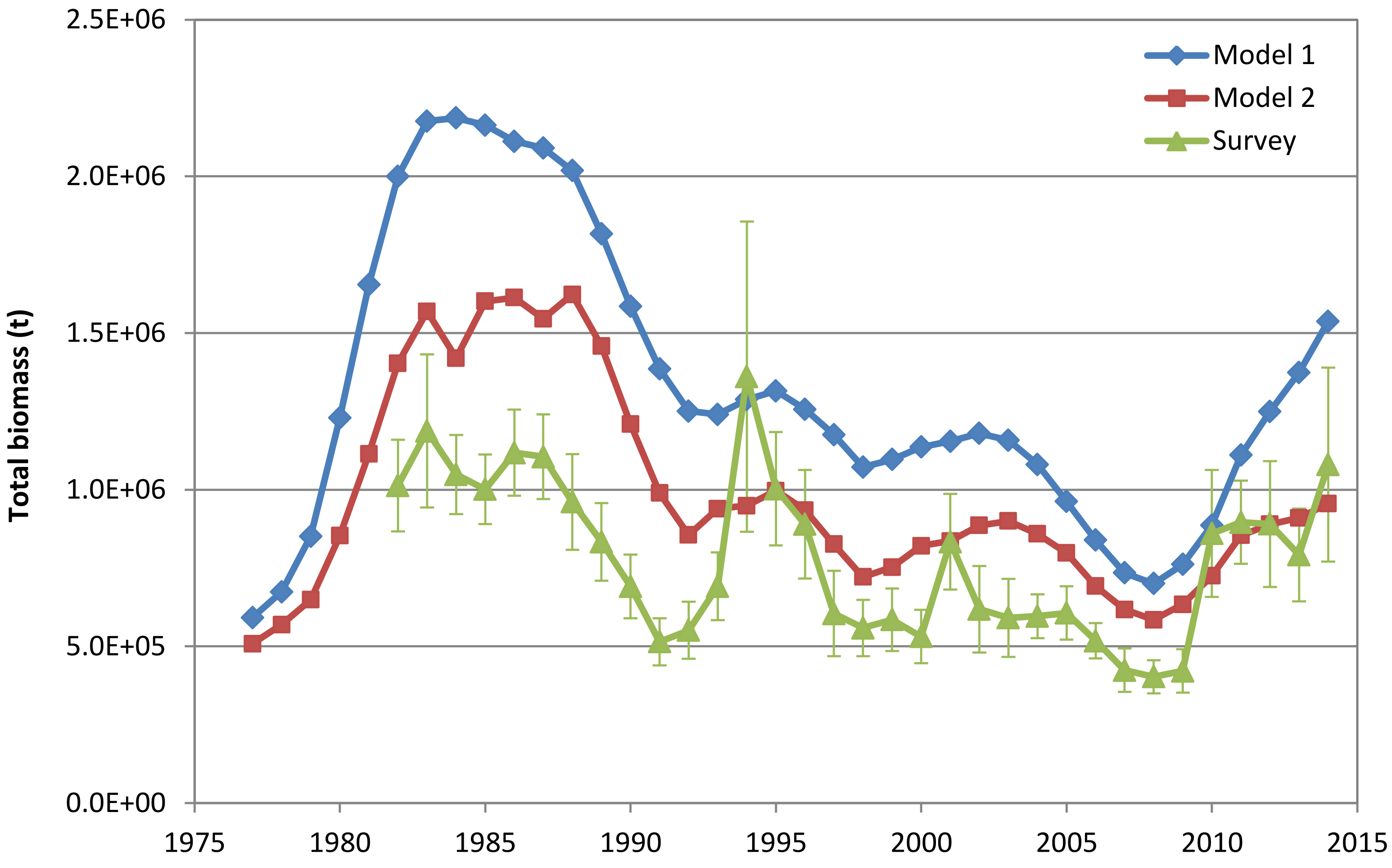
Age 0+ biomass time series (with survey)



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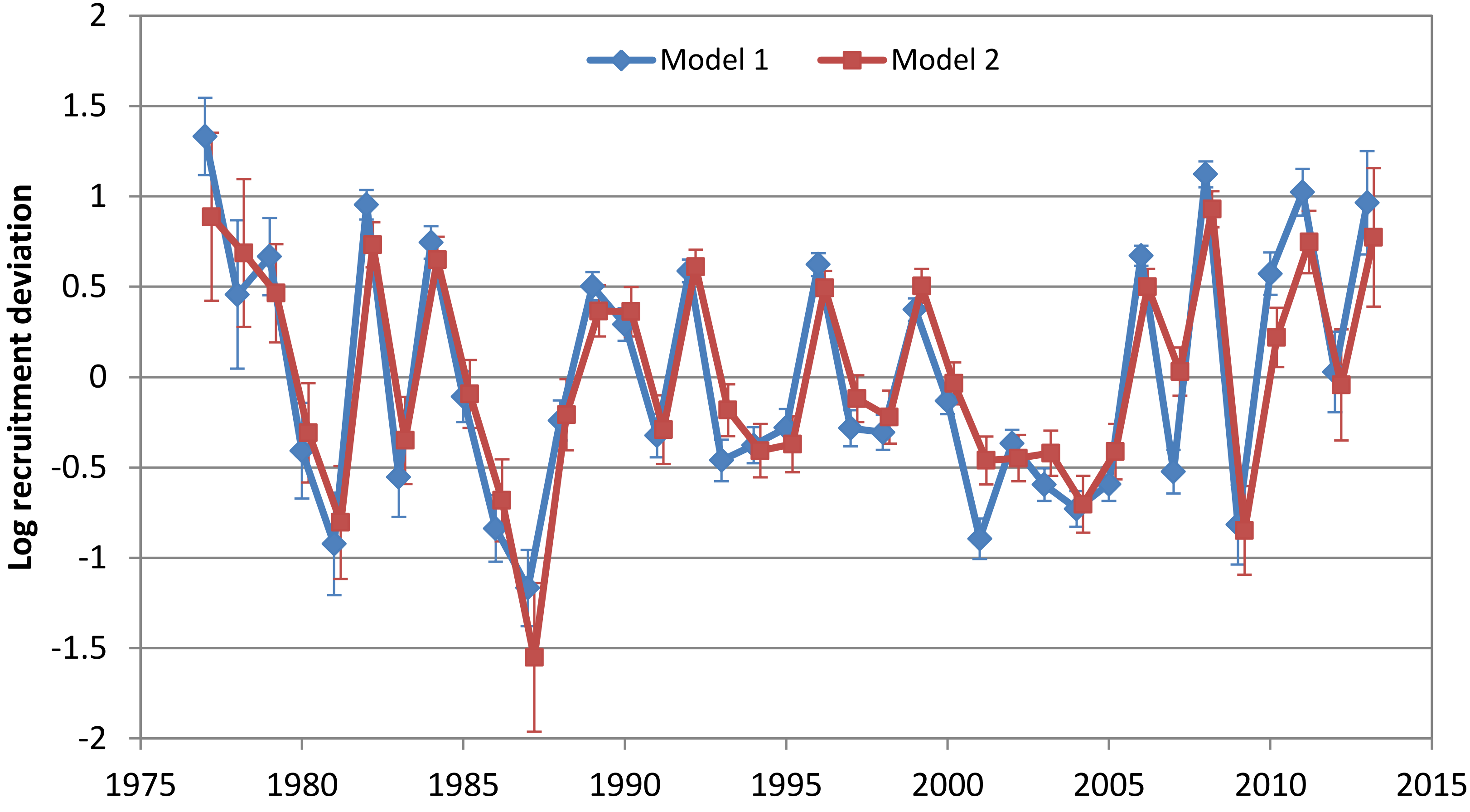
Age 0 recruitment deviations



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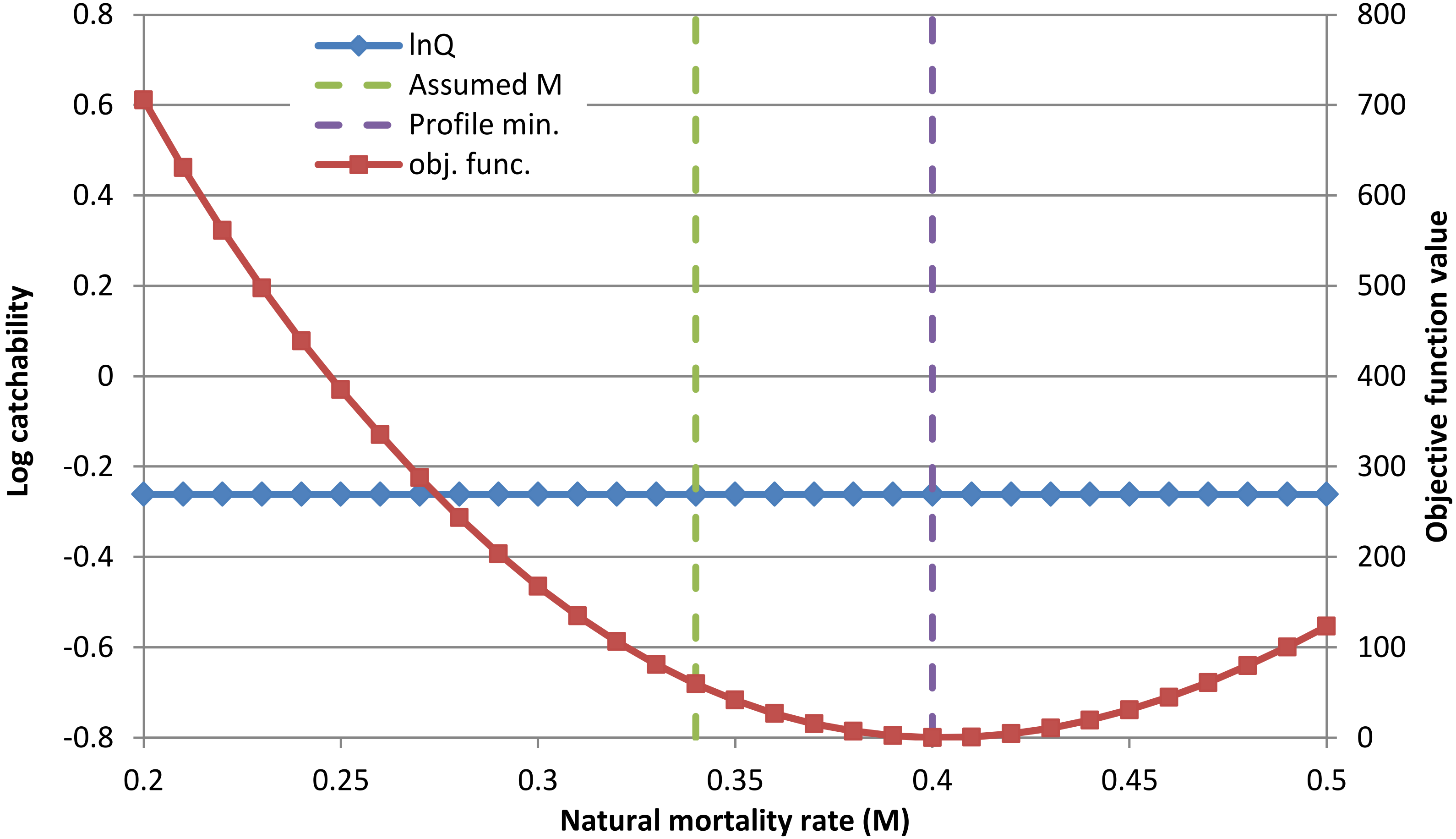
Likelihood profile w.r.t. *M* (Model 1)



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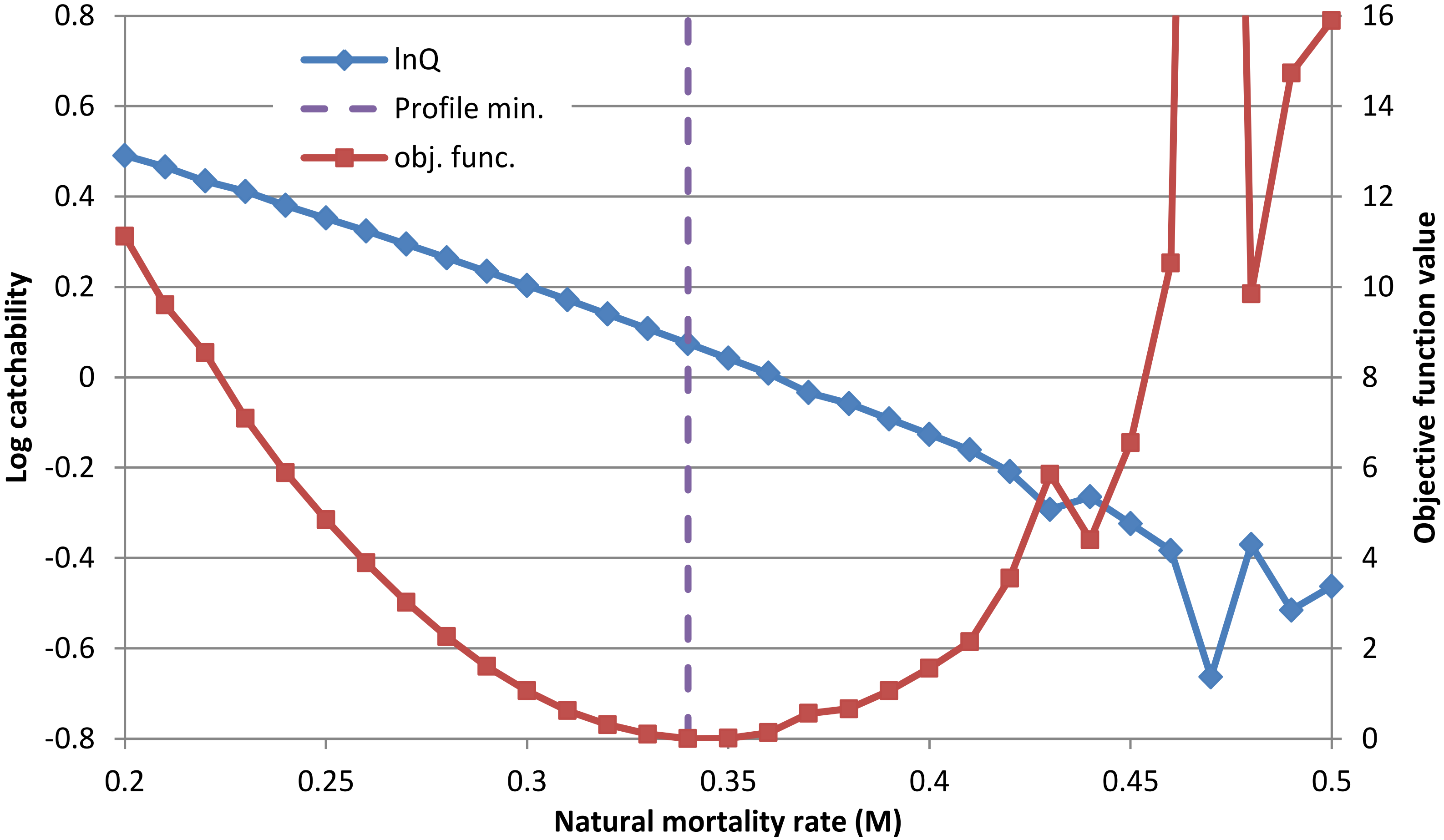
Likelihood profile w.r.t. *M* (Model 2)



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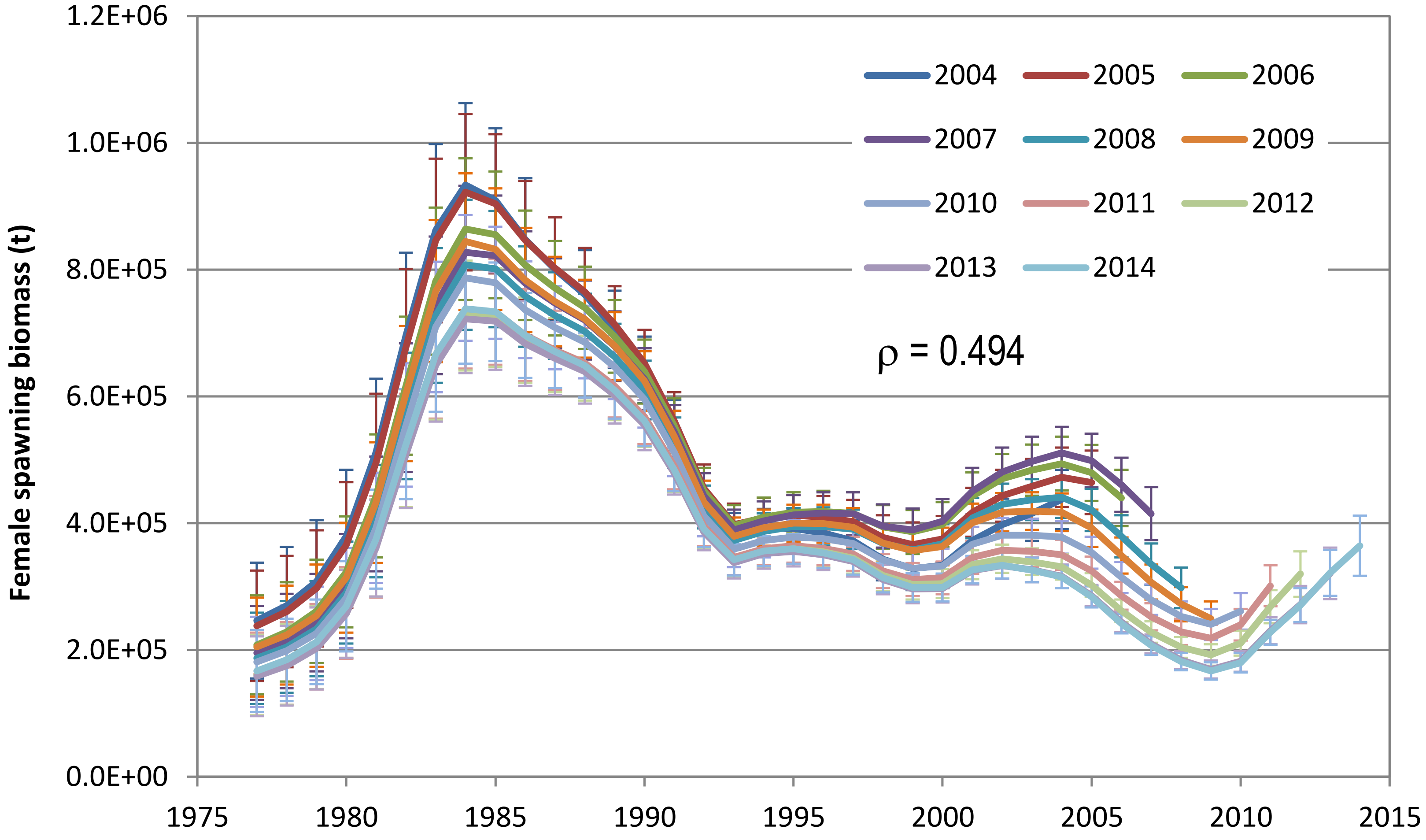
Spawning biomass retrospective (Model 1)



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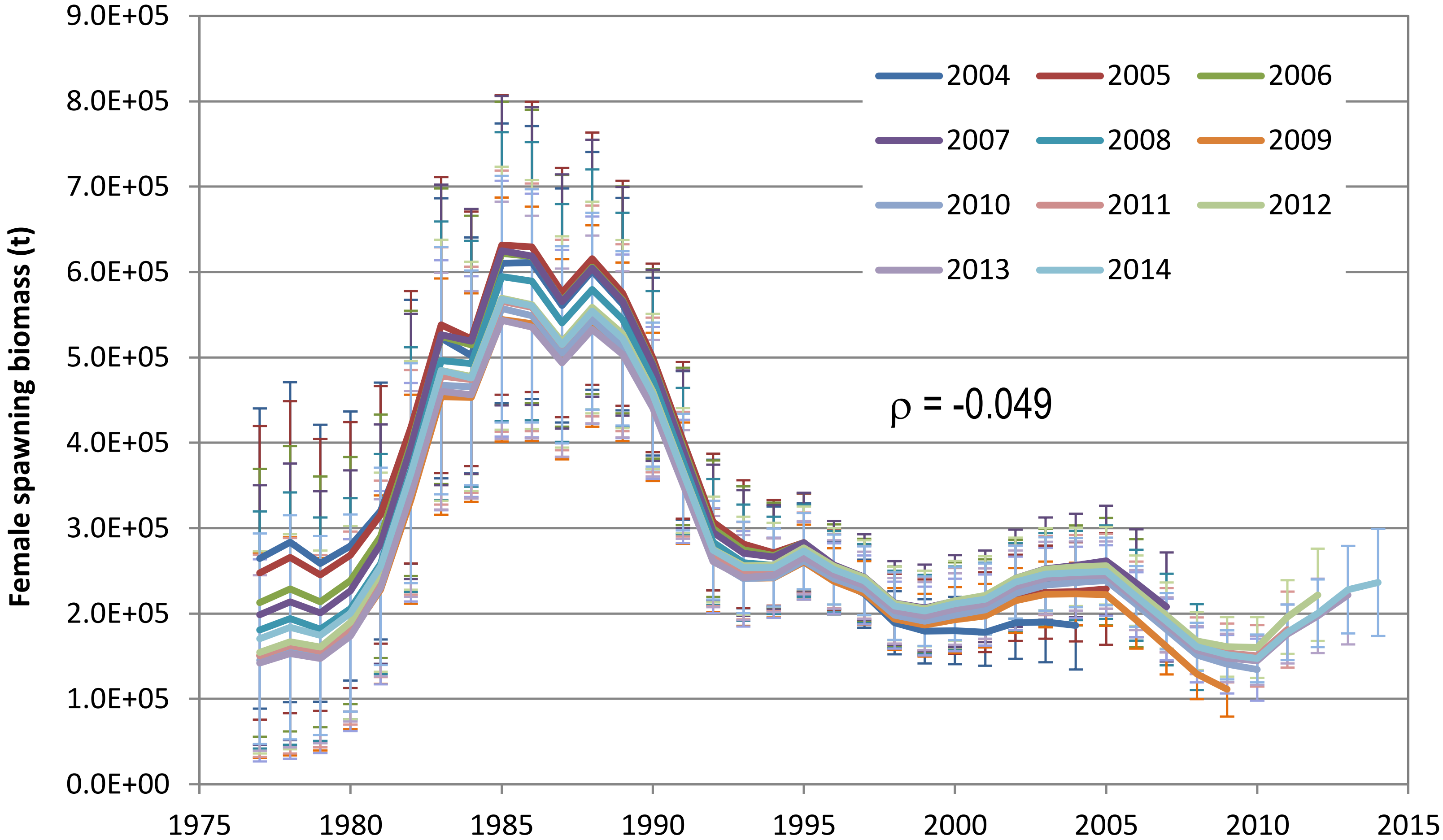
Spawning biomass retrospective (Model 2)



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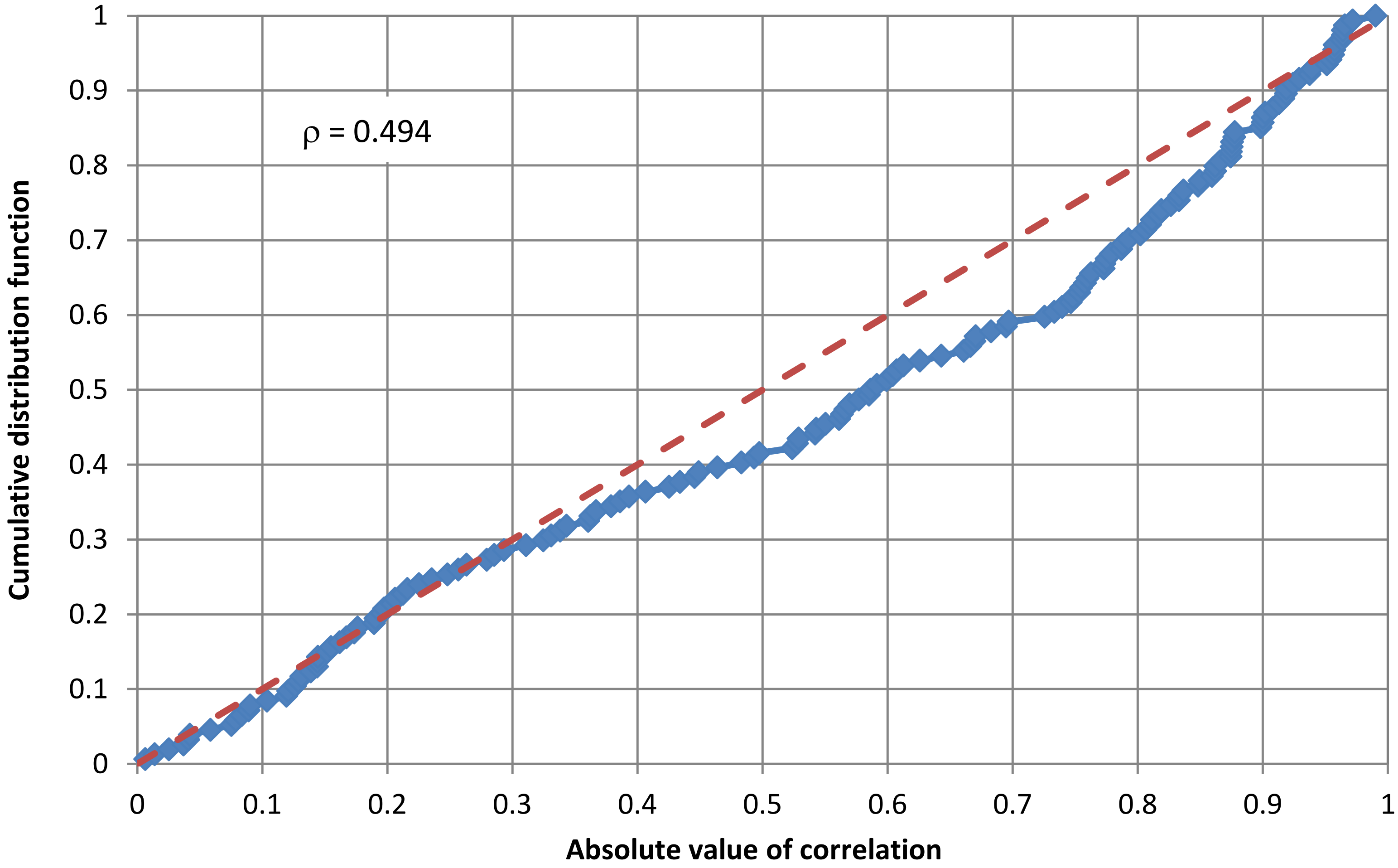
Parameter:peel correlations (Model 1)



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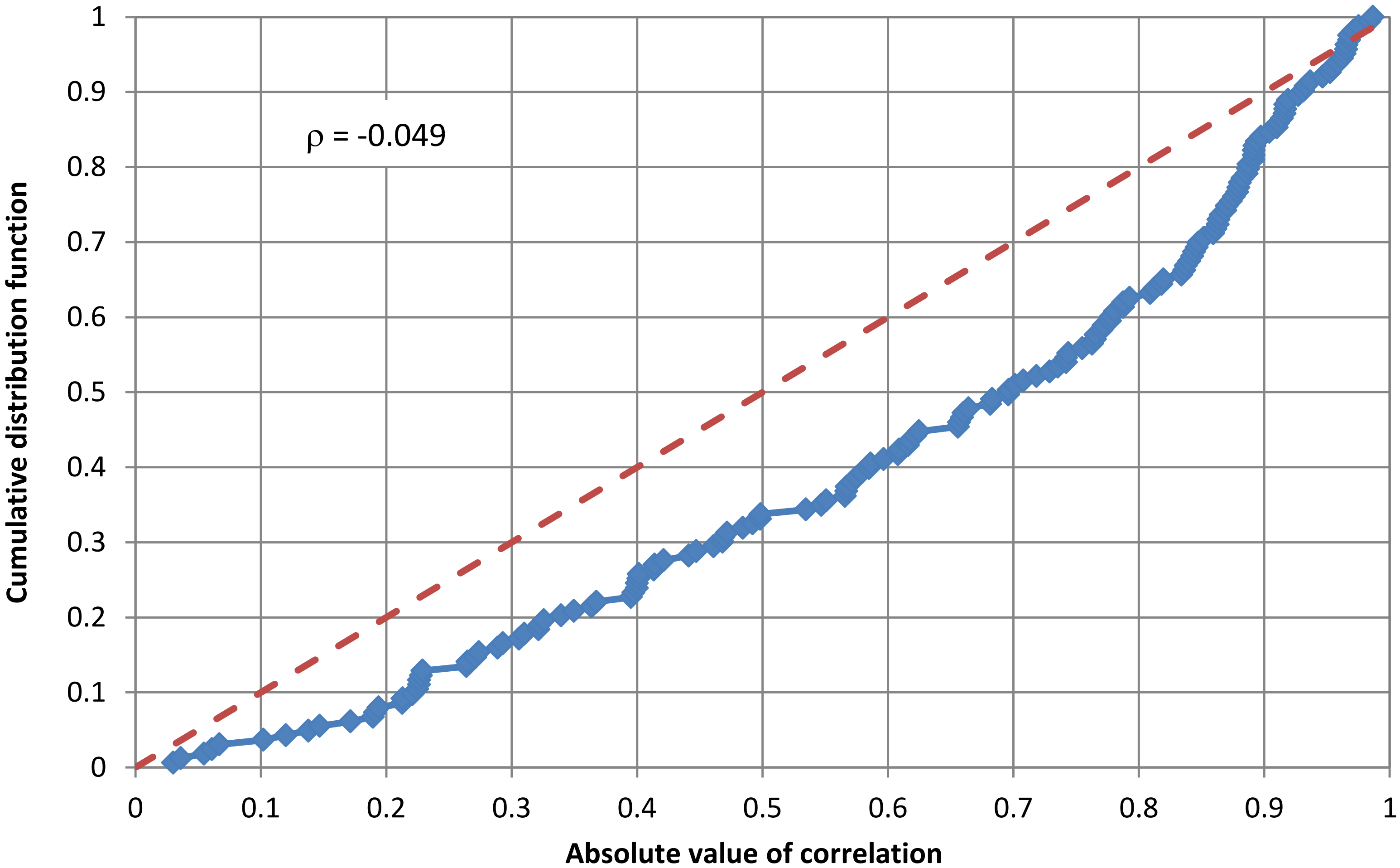
Parameter:peel correlations (Model 2)



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Final model and projections

Model evaluation criteria

- These are the criteria used by the author:
  1. Does the model satisfy the SSC's requests that model changes be kept to a minimum?
  2. Does the model contain new features that merit further evaluation before being adopted?
  3. Would use of the model for setting 2015-2016 harvest specifications pose a significant risk to the stock?

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Evaluation with respect to criterion #1

- Excerpts from relevant SSC minutes:
  - 6/12 minutes: *"…Given the Plan Team's (and SSC's) reluctance in previous years to consider a new author-recommended model in the fall that incorporates a large number of potentially influential changes in a single model (for example changes in growth, selectivities, and catchability), the SSC encourages the authors to evaluate changes in one or a few structural elements at a time."*
  - 6/13 minutes: *"The SSC recommends that model changes be kept to a minimum to ensure that we can track model sensitivities to specific changes in model structure."*
  - 12/13 minutes: *"…The SSC discussed the need for a more incremental approach to implementing changes to the model…."*
- Because Model 1 is the base model, adopting it would, by definition, keep the number of model changes to a minimum
- Model 2 contains a large number of potentially influential changes, including changes in growth, selectivity, and catchability; and does not satisfy the stated need for a more incremental approach to implementing changes

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Evaluation with respect to criterion #2

- In the context of the second criterion, one new feature of Model 2 that stands out is its use of SS selectivity pattern #17, which treats selectivity as a random walk with respect to age
- Although this pattern has several benefits (see “Discussion” section in Appendix 2.1), some aspects could benefit from further evaluation, specifically:
  - Selectivity pattern #17 involves internal rescaling so that selectivity reaches a peak value of unity at some integer age
    - Restricting peak selectivity to occur at an integer age means that the function is not entirely differentiable
  - Although a substantial improvement in goodness of fit can sometimes be achieved by allowing annual $devs$ at the age of peak selectivity, this is sometimes accompanied by a large final gradient in the objective function (most likely related to the item in the previous bullet), which is usually considered to be symptomatic of a problem with the model
  - In some situations, a substantial improvement in goodness of fit can be achieved by estimating selectivity at unrealistically low values for all ages except for a few that are very close to the age-plus group

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Evaluation with respect to criterion #3

- Model 1 estimates a much higher maximum permissible ABC than Model 2
- Model 1 appears to over-estimate the size of the stock by a substantial amount consistently (ρ = 0.494), in contrast to Model 2, which appears to show almost no systematic over- or under-estimation (ρ = -0.049)
- *If* ABC were set at the maximum permissible level, and *if* the stock were at a low level of abundance, this suggests that adoption of Model 1 might impose an unacceptable risk to the stock
- However, it is not necessary to set ABC at the maximum permissible level, neither model suggests that spawning biomass is dangerously low, and both models suggest that spawning biomass has been increasing steadily since 2009 or 2010
- Although adoption of Model 1 would result in the seventh-highest OFL in history, catches of Pacific cod have never exceeded ABC during the last 20 years, so OFL may not be much of a consideration in practice
- Overall conclusion: adopt Model 1 for this year

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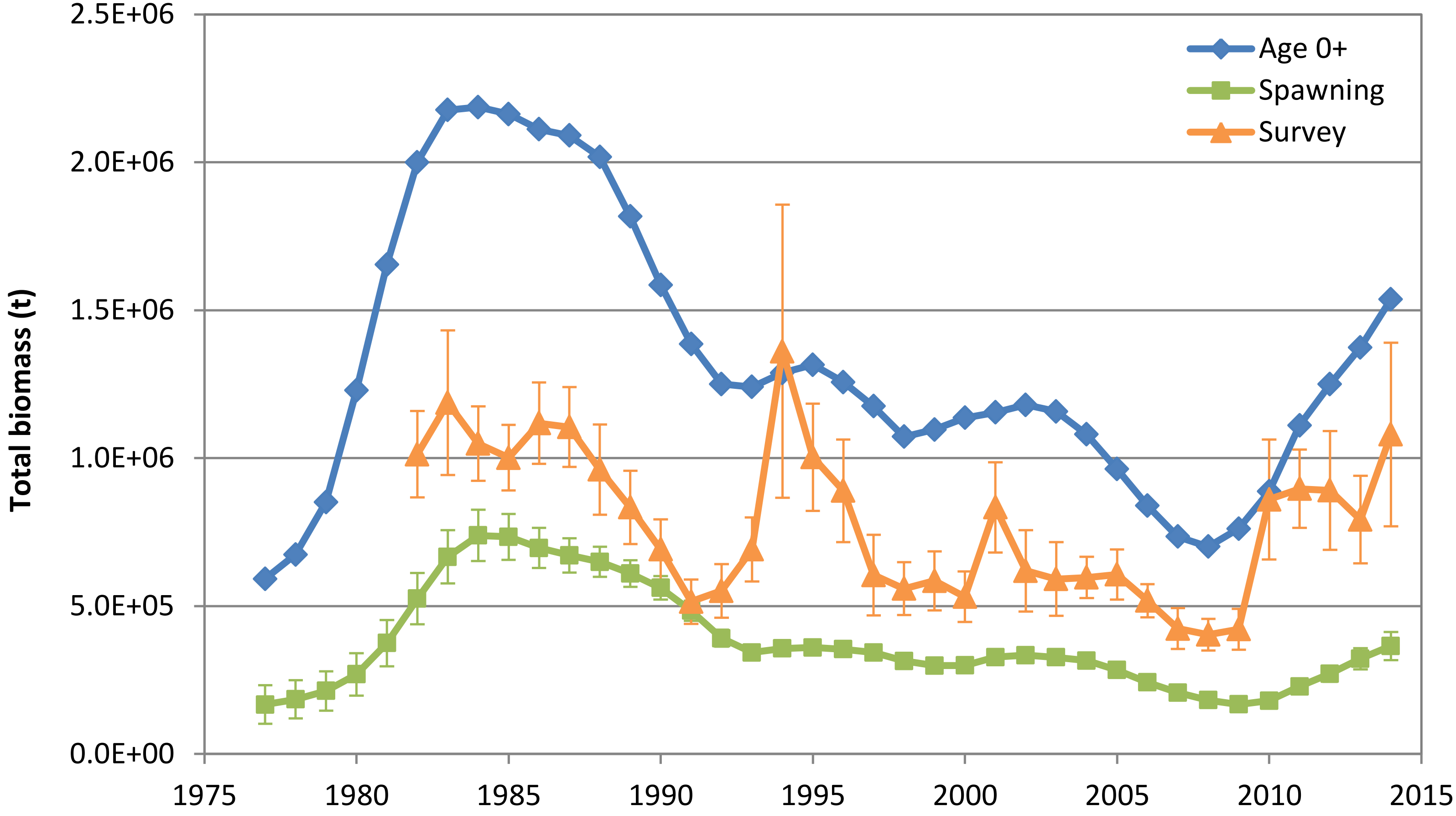
Biomass time series (Model 1)



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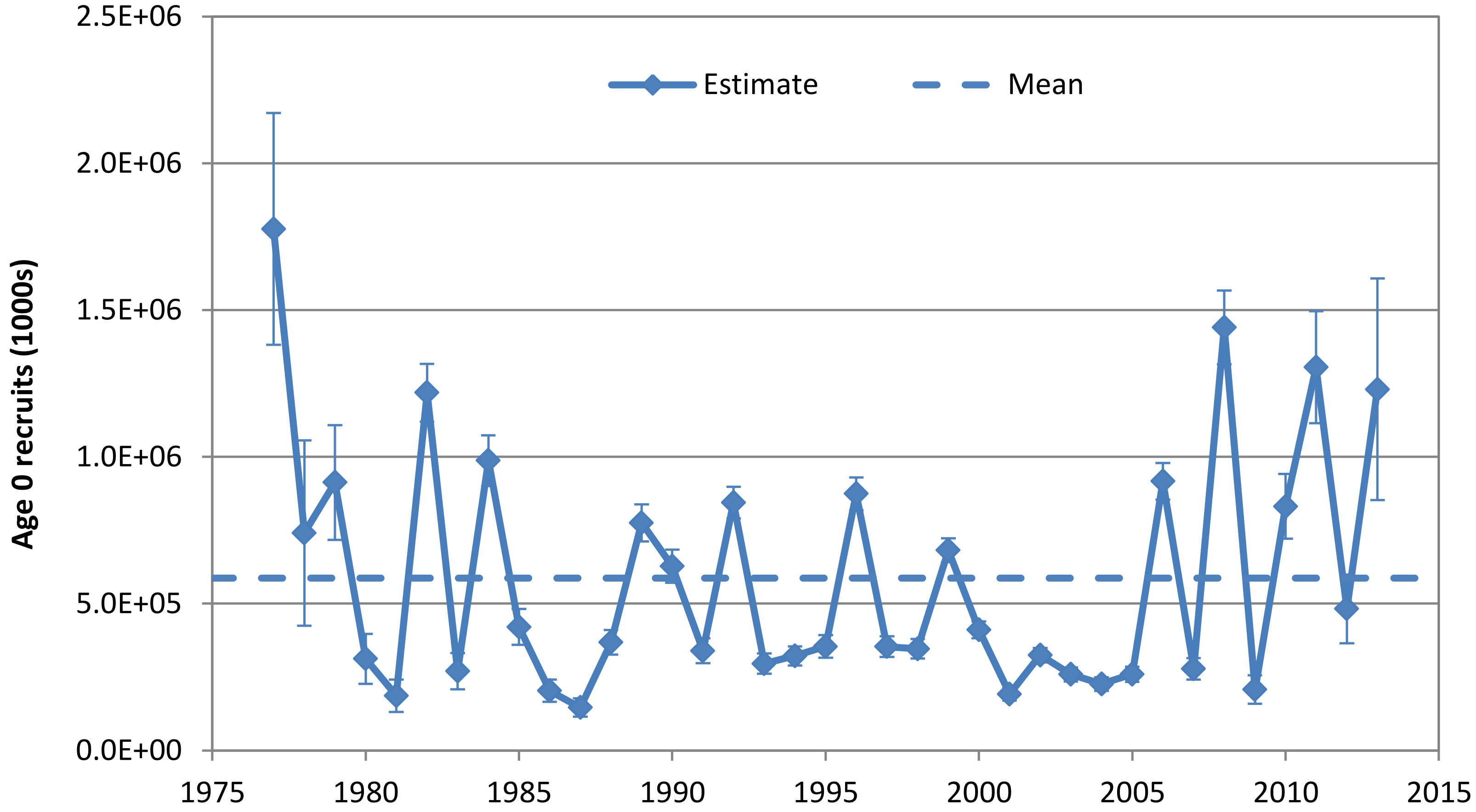
Recruitment (age 0) time series



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Current-year catch estimation (1 of 3)

- Twelve estimators (2 groups of 6) examined overall
  - Each group examined running averages of 1-6 years
- First group used "absolute" catch
  - Year-end catch for current year = catch through August + average Sep-Dec *catch* from last *N* yrs
- Second group used "relative" catch
  - Year-end catch for current year = catch through August / average Jan-Aug *proportion* from last *N* yrs
- Results:
  - All group 1 estimators did better than all group 2 estimators
  - Best group 1 estimator used *N*=1 (log-scale RMSE = 0.07)

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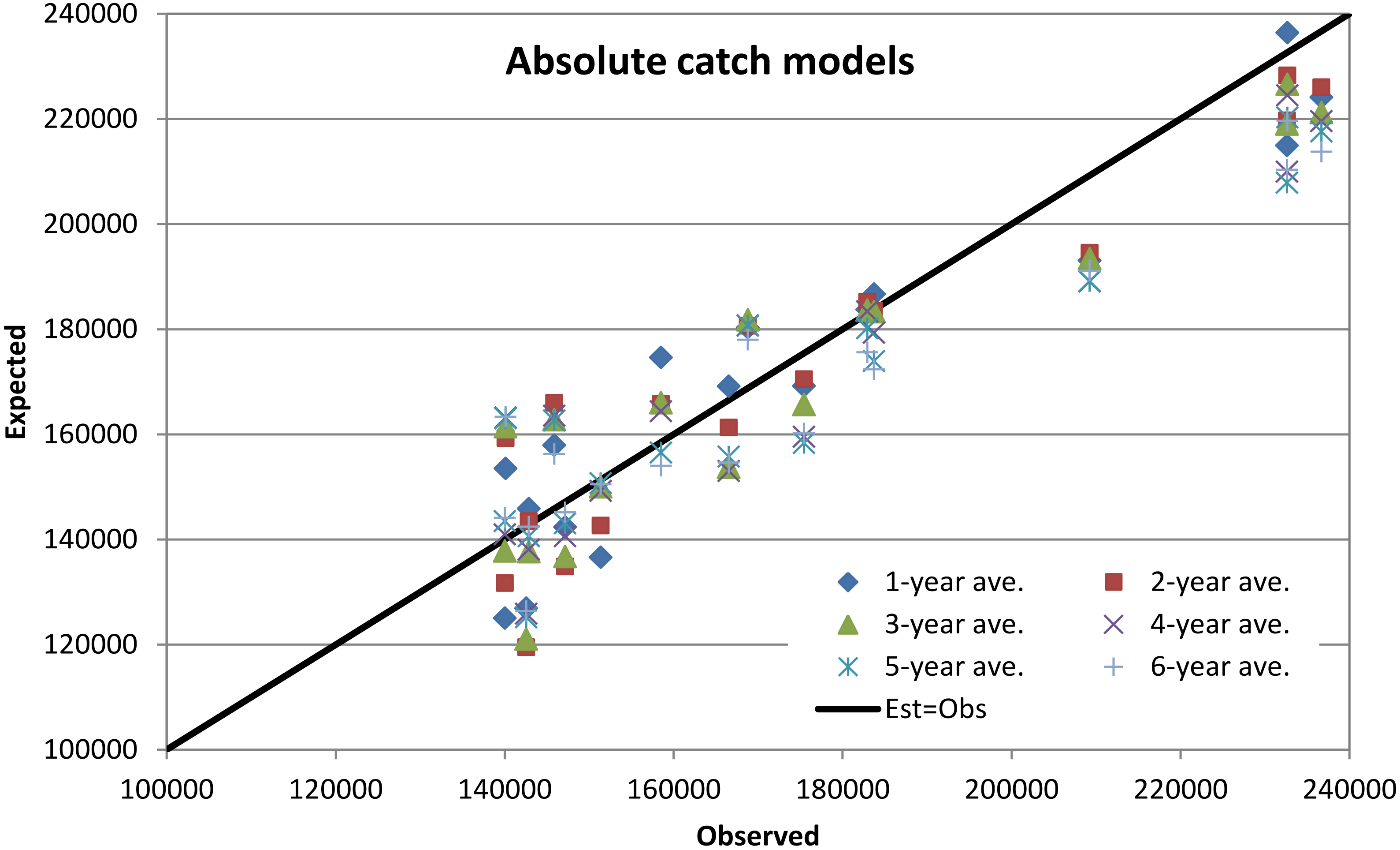
Current-year catch estimation (2 of 3)



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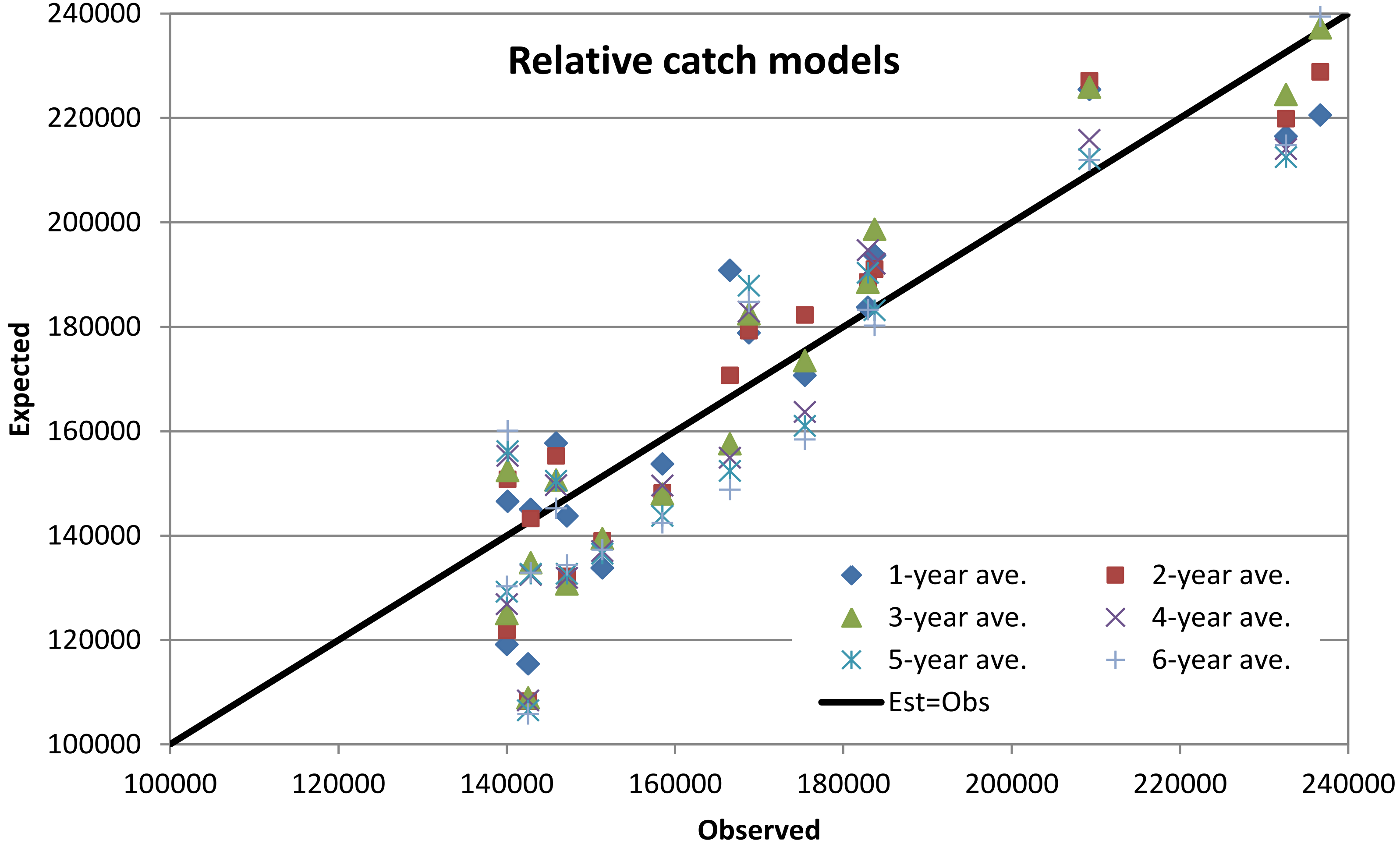
Current-year catch estimation (3 of 3)



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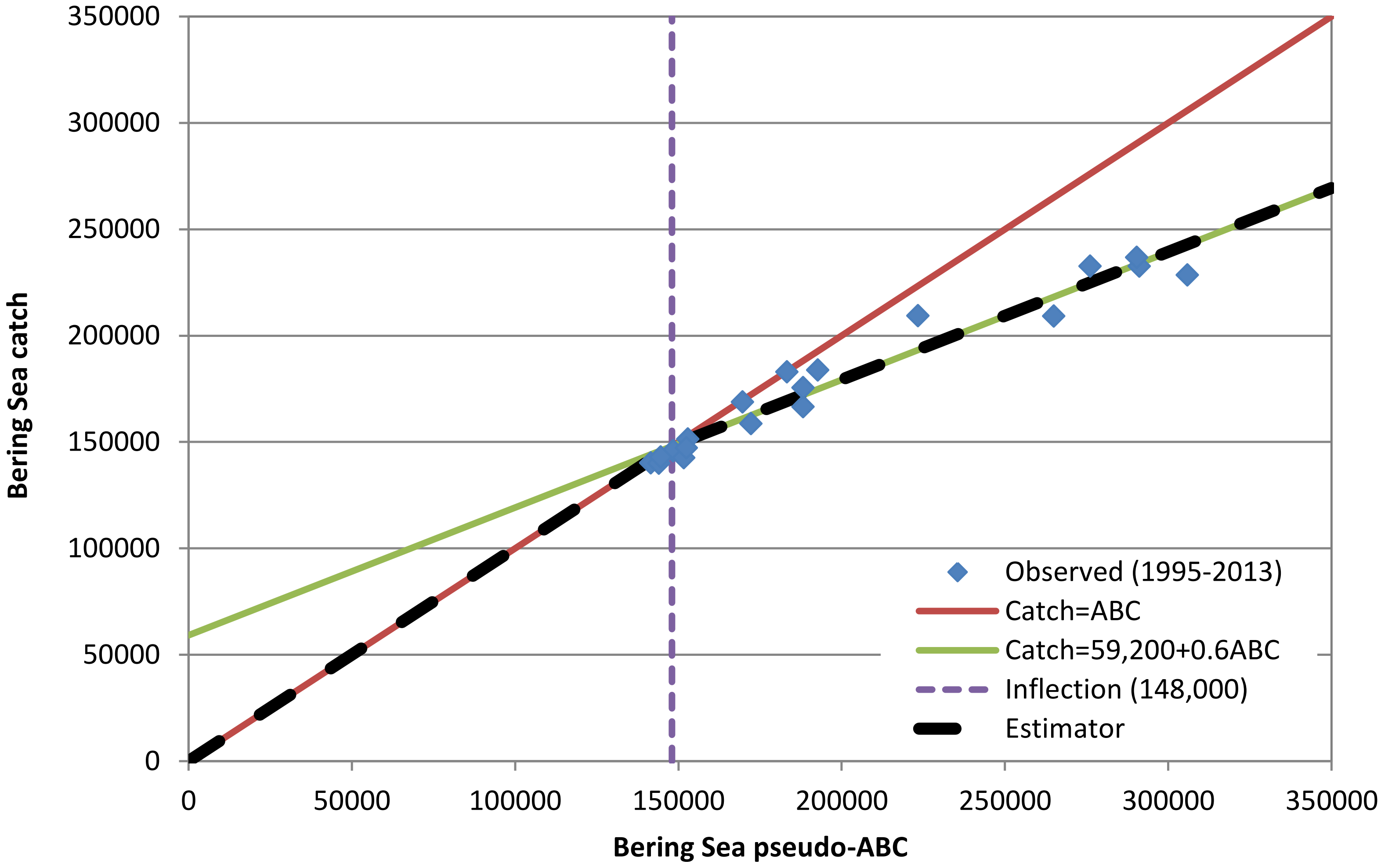
Future-year catch estimation



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ABC recommendation (1 of 3)

- Since 2005, the SSC has set ABC at the maximum permissible level every year with the exception of the 2007 assessment cycle, when the SSC held the 2008-2009 ABCs constant at the 2007 level
- In the present assessment, spawning biomass is estimated to be well above $B_{40\%}$, and is projected to increase further
  - These increases are fueled largely by the 2006, 2008, and 2010, and 2011 year classes, whose strengths have now been confirmed by multiple surveys
  - The 2013 year class also appears to be strong, although this result is highly preliminary, being based entirely on the results of this year's survey.
- At the same time, the continuing concerns regarding estimation of survey catchability should be kept in mind
  - The present estimate, upon which the above projections depend, is based on an extremely small sample size (Nichol et al. 2007), implying that there is considerable uncertainty surrounding the point estimate
  - When catchability was estimated freely in the 2013 preliminary assessment (Thompson 2013, Appendix 2.1), the estimate went up substantially, and the estimate of 2012 spawning biomass dropped by 56%

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ABC recommendation (2 of 3)

- The Team and SSC have also suggested that Q may need to be revised upward:
  - SSC, 10/13: *"In addition to the recommended model configurations, the SSC would like to see a model or models that fix survey catchability at Q=1…. Our rationale for this request is based on the increasing evidence that catchability is higher and quite possibly much higher than the current standard assumption…."*
  - SSC, 12/13: *"The SSC re-iterates its concerns over the best value for the catchability coefficient…. The default assumption in most assessments is that survey catchability is 1, unless there is strong evidence to the contrary. The evidence for a lower Q has been put into question based on recent work…."*
  - Team, 9/14: *"All of the recent field work done by RACE has indicated that the bulk of the cod are very near the bottom when the survey trawl passes, contradicting the conclusion from the tag data. This suggests that catchability is near 1…."*
  - SSC, 10/14: *"Recent acoustic field work conducted by AFSC/RACE indicates that the bulk of the cod biomass is very near the bottom when the survey trawl passes, which is in contradiction to the archival tag data. This suggests that catchability is near 1…."*

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ABC recommendation (3 of 3)

- Finally, there is the issue of the apparently large and positive retrospective bias in Model 1's estimates of current-year spawning biomass
- The amount of bias, while almost always positive, varies from year to year
- Moreover, there does not appear to be a scientific consensus as to the appropriate management response to the existence of a retrospective bias, at least not in very precise terms
- However, it is probably fair to conclude that the existence of a positive retrospective bias does not argue in favor of increasing the Pacific cod ABC for 2015
- As noted above, there is precedent (*viz.*, the 2007 assessment cycle) for holding ABC constant when the assessment involves an inordinate level of uncertainty
- Given all of the above, it does not seem appropriate to recommend an increase in ABC at this time
- The recommended ABC for 2015 is therefore the same as the current (2014) value of 255,000 t
- Holding fishing mortality constant at the rate that results in a 2015 ABC of 255,000 t (85.4% of *max* F_{ABC}) gives a 2016 ABC of 287,000 t, which is the recommended ABC for 2016

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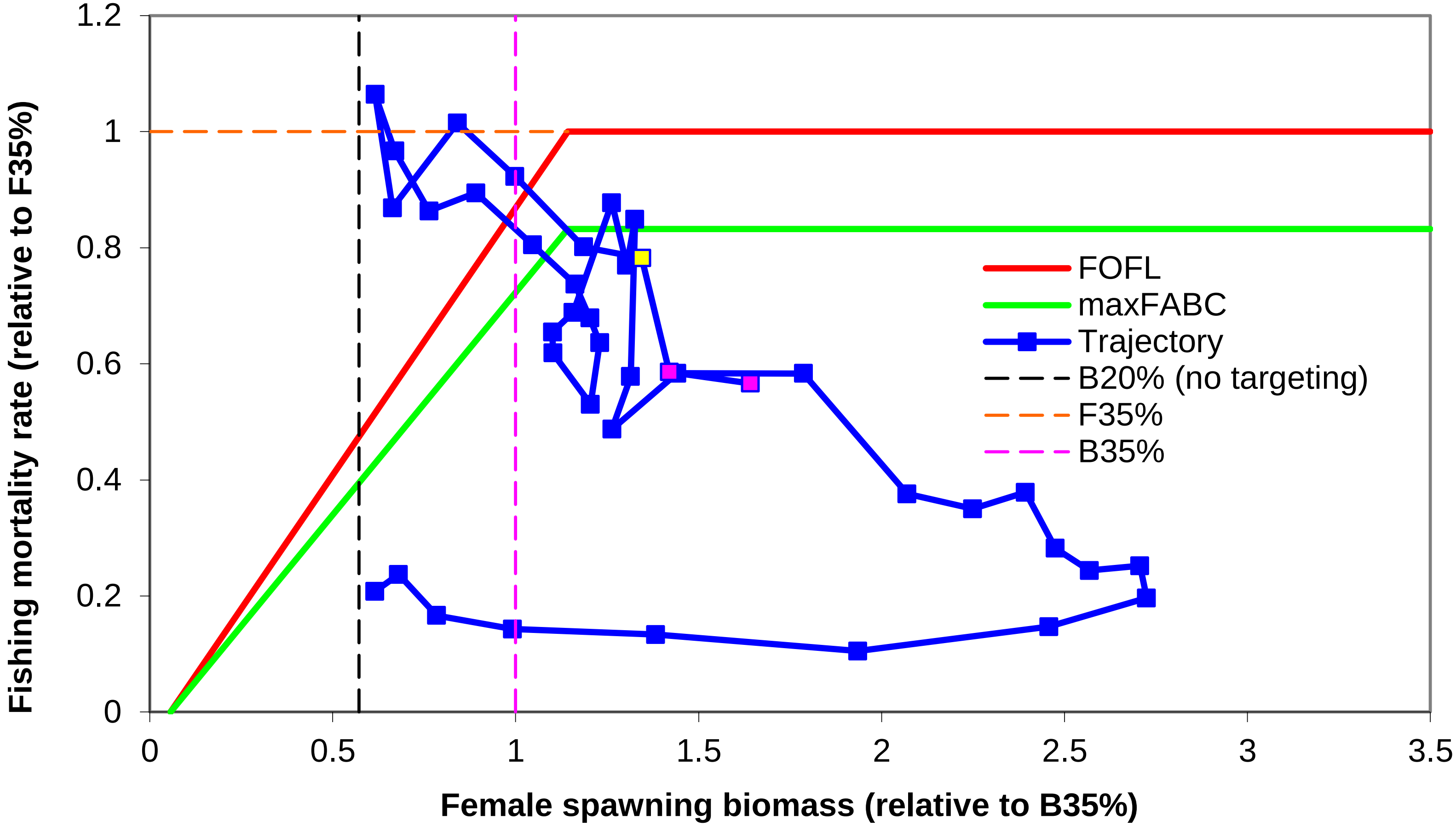
Fishing mortality versus spawning biomass



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Management reference points

Quantity	Model 1	Model 2
B100%	824,000	714,000
B40%	330,000	286,000
B35%	288,000	250,000
B(2015)	409,000	213,000
B(2016)	473,000	269,000
B(2015)/B100%	0.50	0.30
B(2016)/B100%	0.57	0.38
F40%	0.29	0.34
F35%	0.35	0.41
maxFABC(2015)	0.29	0.25
maxFABC(2016)	0.29	0.32
maxABC(2015)	295,000	112,000
maxABC(2016)	316,000	190,000
FOFL(2015)	0.35	0.30
FOFL(2016)	0.35	0.39
OFL(2015)	346,000	132,000
OFL(2016)	389,000	221,000
Pr(maxABC(2015)>truOFL(2015))	0.01	0.33
Pr(maxABC(2016)>truOFL(2016))	0.03	0.32
Pr(B(2015)<B20%)	0.00	0.02
Pr(B(2016)<B20%)	0.00	0.00
Pr(B(2017)<B20%)	0.00	0.00
Pr(B(2018)<B20%)	0.00	0.00
Pr(B(2019)<B20%)	0.00	0.00

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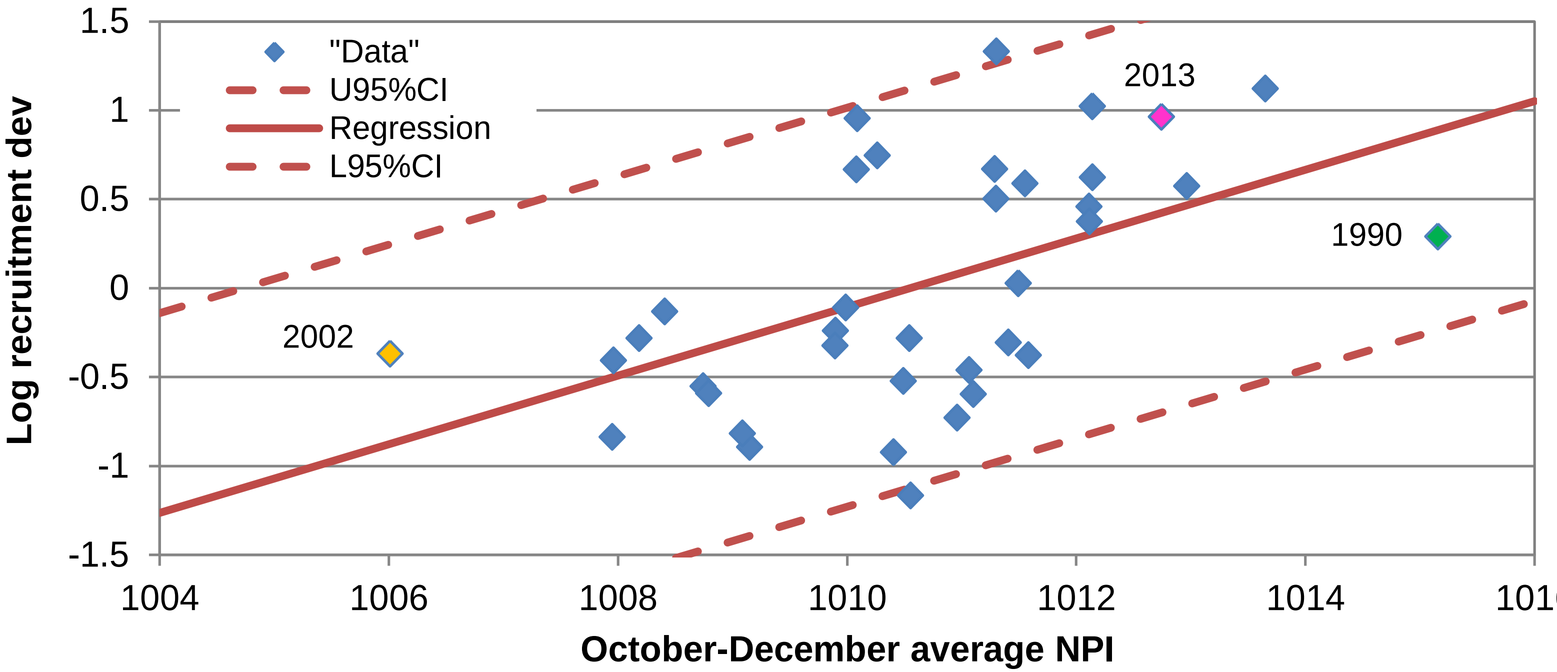
Ecosystem considerations and research priorities

An environmental predictor of recruitment

- Recruitment varies directly with Oct-Dec average NPI
- Correlation = 0.54, R^2 = 0.29



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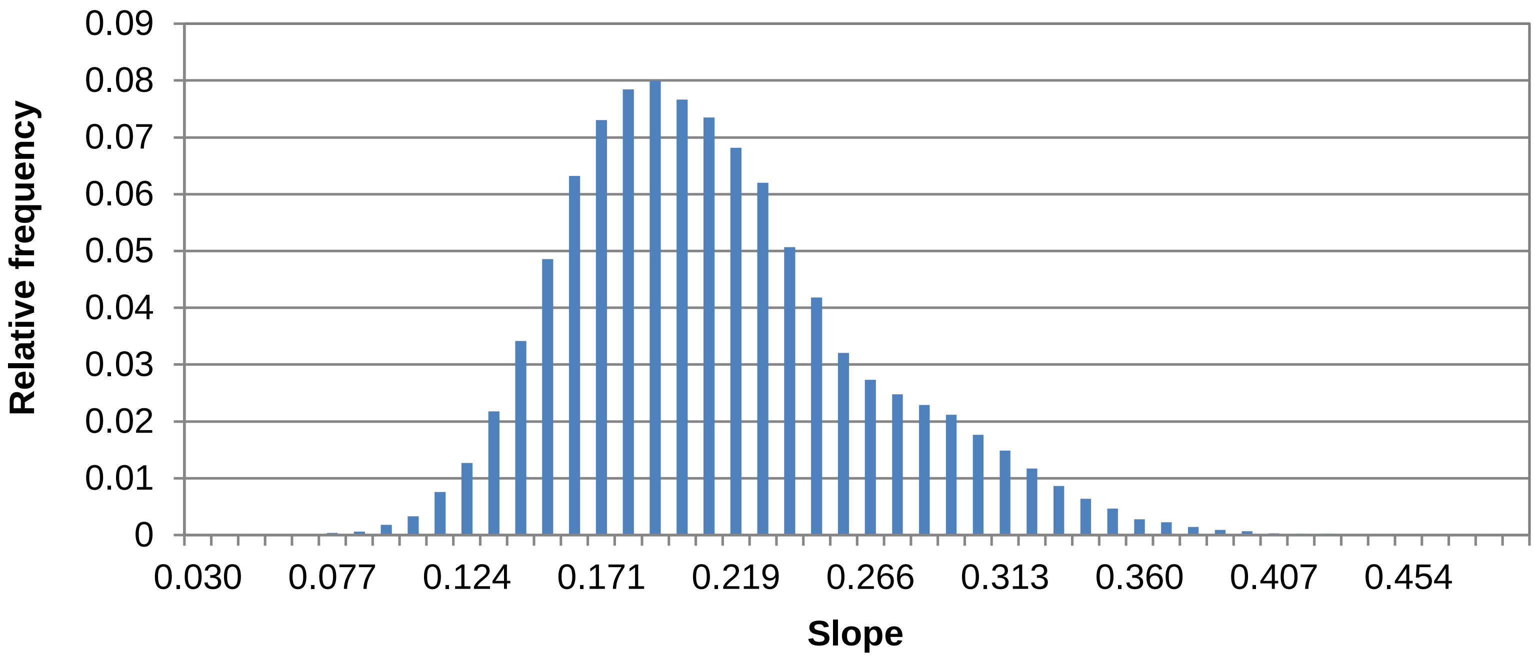
Cross validation (50% random samples)

- RMSE from *test* sets: 0.69 without NPI, 0.61 with NPI
- Distribution of slope estimates from *training* sets



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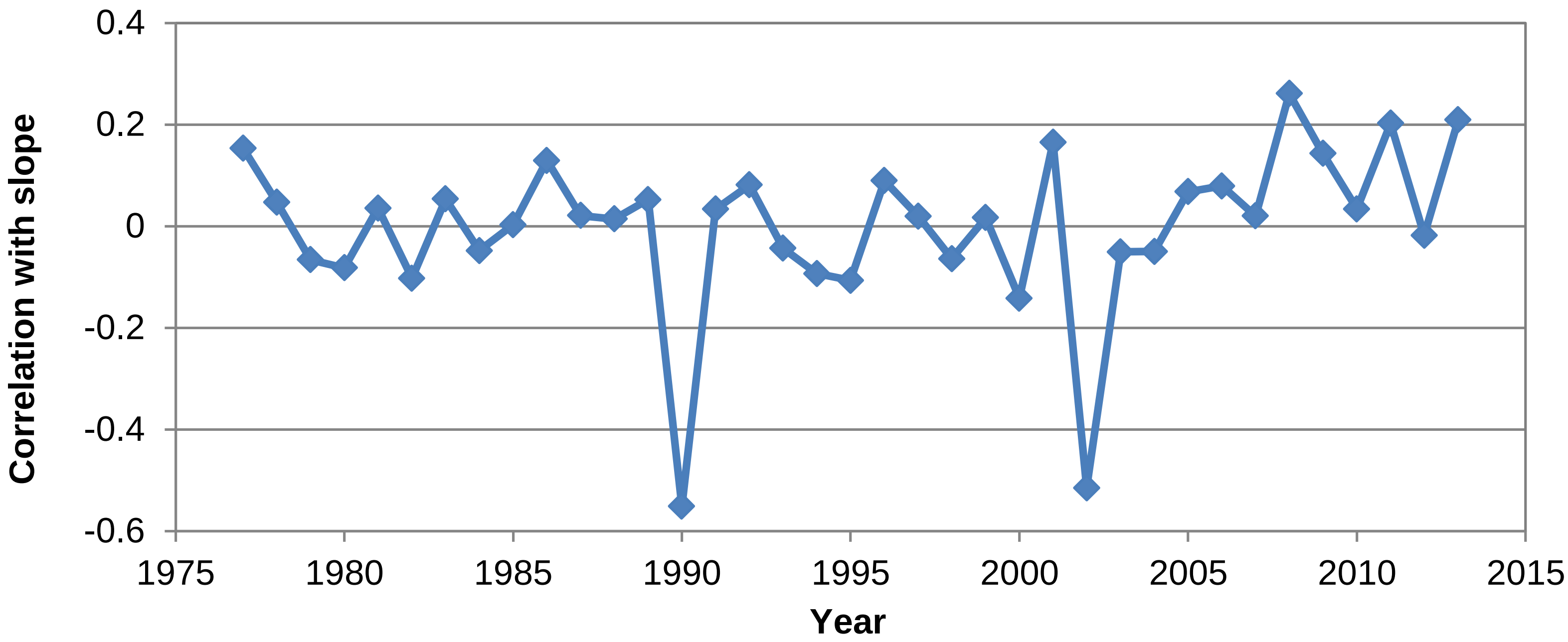
Impact of individual years on slope estimate

- 1990 and 2002 have strongest impact on slope, and both of those are in the negative direction



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Research priorities

- At this point, the most critical needs pertain to trawl survey catchability and selectivity, specifically:
  1. To understand the factors determining these characteristics
  2. To understand whether/how these characteristics change over time
  3. To obtain accurate estimates of these characteristics
- Ageing also continues to be an issue, as the assessment models consistently estimate a positive ageing bias
- Longer-term research needs include improved understanding of
  1. Ecology of Pacific cod in the EBS, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment
  2. Ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience
  3. Ecology of species that interact with Pacific cod, including estimation of interaction strengths, biomass, carrying capacity, and resilience